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NEARSHORE FISH AND MACROINVERTEBRATE ASSEMBLAGES ALONG THE STRAIT OF JUAN DE FUCA INCLUDING FOOD HABITS OF NEARSHORE FISH

by

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ABSTRACT

In response to potential oil shipment to or through the Strait of Juan de Fuca, a baseline study was initiated to document the distribution, abundance, and biomass of the nearshore fish, to determine the food habits of the fish and to identify and catalogue the macroinvertebrates collected incidentally with the fish.

Seventy species of fish were collected by beach seine (demersal fishes) and townet (neritic species). Species richness increased from west to east. Fish were generally most abundant during the summer; reduced abundances typified winter collections. Standing crop was greatest during summer and fall and least during winter and spring.

The dominant nearshore demersal species were the sand sole, English sole, and Pacific staghorn sculpin. The dominant nearshore neritic species were the Pacific herring, longfin smelt, walleye pollock, and shiner perch.

One hundred and fifteen species of macroinvertebrates were collected with the fish. Decapod and amphipod crustaceans were the most abundant organisms collected. Species richness generally increased from west to east. The highest values were usually recorded during the spring and the lowest during the fall.

The stomachs of more than 1,500 specimens of 61 nearshore fish species were examined. Nearshore demersal fish fed predominantly upon epibenthic crustaceans (harpacticoid copepods, mysids, cumaceans, tanaids, isopods, gammarid amphipods, and shrimp). Nearshore neritic fishes most frequently preyed upon pelagic invertebrates (calanoid copepods, euphasids, larvaceans, hyperiid and gammarid amphipods, and fishes).

I. INTRODUCTION

The possibility of transport of Alaskan North Slope oil to proposed refinery and transshipment sites in the Strait of Juan de Fuca or Puget Sound raises the probability of increased oil pollution in these waters. Under proposals presently being considered, this oil could be transferred to refinery, holding, or pipeline facilities at one of a number of sites such as Port Angeles on the Strait of Juan de Fuca or Cherry Point and Anacortes on the eastern shore of Rosario Strait.

The State of Washington and federal agencies, concerned with minimizing the incidence and impact of oil pollution, have conducted a number of programs designed to evaluate the detrimental effects of oil pollution on the biological and economic resources of Puget Sound. One of these, the Washington State Department of Ecology's (DOE) Northern Puget Sound Biological Baseline Study, initiated in 1974, focused on documenting biological communities in the nearshore habitats of northern Puget Sound.

Since the eastern Strait of Juan de Fuca has come under consideration as a possible oil transshipment terminal site, the National Oceanic and Atmospheric Administration's (NOAA) Marine Ecosystem Analysis (MESA) Puget Sound Project initiated similar biological baseline studies in the Strait of Juan de Fuca. One important element of the NOAA studies is an ecological survey of nearshore fish assemblages and their food web relationships. Emphasis was placed on nearshore fishes because: 1) They provide a direct link to man for the transfer and accumulation of petroleum hydrocarbon pollutants; and 2) they are likely to be exposed to these pollutants, as they feed and live in habitats most vulnerable to oil spill impact and retention.

The principal objectives of this study were to document: 1) The occurrence, abundance, and distribution of nearshore fishes; 2) food habits of abundant and economically important species; and 3) occurrence and distribution of macroinvertebrates collected incidentally with the fishes.

II. MATERIALS AND METHODS

II-A. Study Sites and Sampling Frequency

One of the main considerations used to determine sampling sites and sampling design was the desire to make the results of the nearshore fish section of the MESA Puget Sound Project comparable to the DOE Northern Puget Sound Biological Baseline Study. This would facilitate inter-area comparisons by habitat. Further considerations used to determine sampling sites were: 1) The desire to sample as much of the Strait of Juan de Fuca as possible; thus sites were fairly evenly spaced on an east-west gradient; 2) sites needed to be accessible to both the land-based beach seine operation and the ship-based townet operation; 3) sites were chosen to reflect the variety of habitats encountered along the Strait of Juan de Fuca.

The sampling gear employed (beach seine and townet) were those utilized in the DOE study. Both types of gear had proved reliable and had yielded consistent samples during the 2-year study.

Sampling sites were characterized by habitat and sampled by two sampling methods (beach seine and townet) specifically designed to capture nearshore demersal and neritic fishes (Fig. 1, Table 1). Beach seining was conducted quarterly during a low tide series to capture nearshore demersal species; townet collections for neritic species generally occurred within a week of beach seining.

Collection periods were scheduled so that one collection was made in each of the four seasons, i.e., January = winter, May = spring, August = summer, October = fall.

II-B. Sampling Techniques

II-B-1. Beach Seine

A 37-m (120-foot) beach seine was used to sample demersal fish occurring within 30 m of shore during slack water at low tide. The

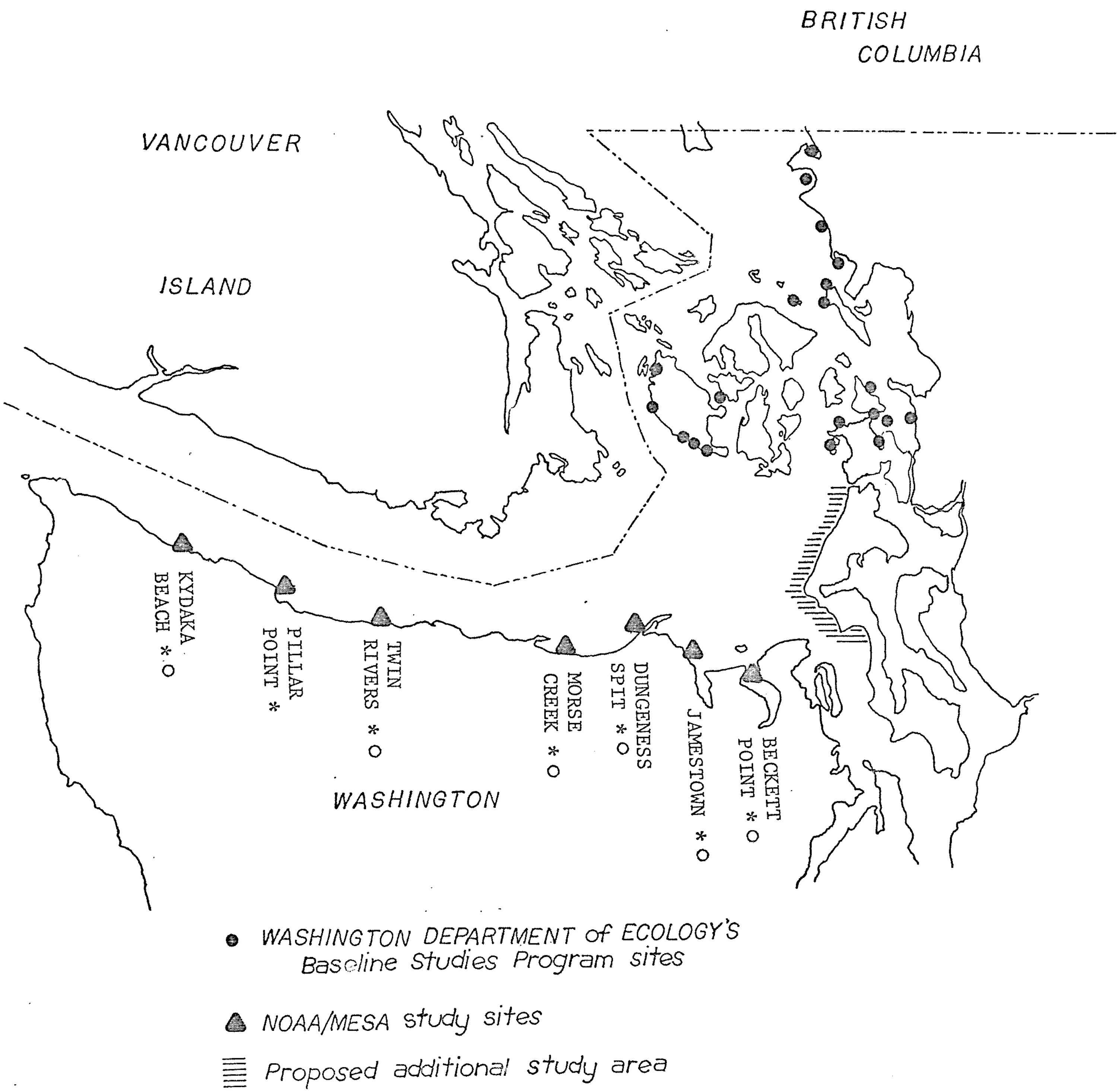

Fig. 1. Location map of sampling sites. Type of gear used: * indicates townet, O indicates beach seine.

Table 1. Characterization of study sites along the Strait of Juan de Fuca. BS = beach seine, TN = townet.

Site	Habitat	Sampling method
Kydaka Beach	High gradient, high energy, direct exposure, sand substrate, no algae, little detritus	BS, TN
Pillar Point	Moderate gradient, moderate energy, moderate exposure, rocky kelp bed with adjacent sand flats	TN
Twin Rivers	Low gradient, moderate energy, moderate exposure, sand and cobble beach, abundant algae and kelp	BS, TN
Dungeness Spit	High gradient, high energy, high exposure, sand and gravel beach, no algae, little detritus	BS, TN
Morse Creek	Low gradient, moderate energy, moderate exposure, sand and cobble beach, abundant algae and kelp	BS, TN
Jamestown	Low gradient, low exposure, low energy, mudflat with extensive eelgrass beds	BS, TN
Beckett Point	Moderate gradient, low exposure, low energy, sand and gravel beach, abundant algae and eelgrass	BS, TN

beach seine consisted of two wings with 3-cm mesh joined to a 0.6-m x 2.4-m x 2.3-m bag with 6-mm mesh. A weighted lead line kept the seine on the bottom. Floating sets were made with seven floats attached to the cork line at regular intervals. The net was set 30 m from shore from the stern of a rowed skiff. Polypropylene lines 30 m long and 2 cm diameter were used to retrieve the net. Two-person teams situated 40 m apart hauled the net at about 10 m/minute. For the first 20 m of hauling the teams remained 40 m apart; the final 10 m was hauled with the teams 10 m apart. When the net was entirely on the beach, fish and invertebrates were removed, placed in plastic bags, and labeled for later processing. Replicate hauls were made at each site except when weather conditions made that impossible. Care was taken so that the area swept by one set was not included in the replicate. Time between sets was at least 30 minutes; this increased with increasing catches. At sites where the depth of water was less than 3 m, only sinking sets were made. Where water depth exceeded 3 m (two sites), both floating and sinking sets were made. Beach seining was conducted during slack water at low tide; this involved sampling at night between October and March and during the day between March and October.

II-B-2. Townet

A two-boat surface trawl (townet) was utilized to sample neritic fish occurring in the upper 3.5 m of the water column adjacent to the shoreline. The townet measured 3 m x 6 m (10 x 20 feet), with mesh sizes grading from 76 mm (3 inches) at the brail to 6 mm (1/4 inch) at the bag. The net was towed at 800 rpm (about 3.7 km/hour) between the 12-m (39-foot) FRI research vessel MALKA and a 3.7-m (12-foot) purse seine skiff. At each site, two 10-minute tows were made. One tow was made with the prevailing tidal current along the shoreline while the other tow was made in the opposite direction.

To reduce net avoidance by pelagic species and to optimize sampling of those pelagic species which migrate into shallow water nocturnally, sampling was conducted at night. We also sought to sample during periods of minimal tidal currents and moonlight to reduce and standardize these sources of variation, but this was not always possible.

The net was towed as close to the shoreline as depth, kelp growth, and flotsam would allow. The net dragged bottom in 5 m (15 feet) of water.

Seldom were we able to follow a consistent transect over the same depth, distance from shore, and length at the townet sites; conditions during the collection periods varied because of tide, flotsam, weather, etc. However, the towing setup proved to be quite maneuverable, allowing us to work along the shoreline rather easily.

II-B-3. Macroinvertebrate Cataloguing

Epibenthic macroinvertebrates were also collected by beach seine at the six sites, and pelagic macroinvertebrates were collected by townet collections at seven sites along the Strait of Juan de Fuca.

The macroinvertebrates were handpicked from the beach seine and townet and placed in 10 percent buffered formalin, except for large, readily identifiable crabs and asteroids which were measured (or estimated) for size and released on the site at the time of collection. Samples were removed to the laboratory and identified, weighed, and measured within 1 to 5 months after collection. Species were sorted using a dissecting microscope. For species occurring in numbers greater than 100, selected subsamples of 50 were weighed and measured, the remainder of the sample was counted, and a total weight was taken.

Weights were taken to the nearest 0.01 g and lengths were measured to the nearest millimeter. Carapace lengths, tip of rostrum to posterior edge of carapace, were taken on the shrimp. In the laboratory, crabs were measured at their widest point (carapace width). Mysids, amphipods, and isopods were measured from the eye to the tip of the telson. All other measurements were total lengths.

Species identifications were made using a variety of dichotomous keys, illustrated references, and descriptions. The principal references used for taxonomic identification included: Banner (1947, 1948, 1950), Barnard (1969), Barnes (1974), Johnson and Snook (1955), Kozloff (1974), Ricketts and Calvin (1968), Schultz (1969), and Smith and Carlton (1975). A reference collection was organized and maintained for the purpose of comparing prey organisms to verified specimens. Amphipods were identified by Craig Staude of Friday Harbor Laboratories.

II-C. Collection Information

For all sampling methods, the following data were recorded: Location, date, time, tide stage and height, weather conditions (air temperature, wind speed and direction, visibility, precipitation, and cloud cover), sea surface temperature, salinity and dissolved oxygen, sea state and color, bottom depth, area sampled (beach seine), volume sampled (townet), distance fished, sampling duration, compass heading, light intensity, and current direction and velocity. All information was recorded on computer data forms.

Water samples were obtained for salinity and dissolved oxygen measurements. For beach seine samples, salinity was determined by the potentiometric method and dissolved oxygen by Winkler titration. During townet collections, salinity was measured with a Beckman salinity-temperature probe, while dissolved oxygen was determined by Winkler titration.

II-D. Biological Information

Catches from the beach seine and townet were bagged, labeled, and placed on ice until processing. Fish retained for stomach analysis were separated from the catch and preserved in 10 percent formalin immediately after collection. A representative sample of macroinvertebrates was collected and bagged separately.

Generally, catches were taken in their entirety. It became necessary to subsample when the catch of one or more species was too large to permit proper handling within the available time. The less abundant species were sorted from the catch and saved. The abundant species were thoroughly mixed and a known volume greater than or equal to 10 percent of the sample was removed and saved. The volume of the remaining sample was measured and the fish were discarded.

II-E. Processing the Catches

Fish samples were sorted to species and individuals were counted, measured (total length), and weighed (to the nearest 0.1 g wet weight). Where possible the following information was taken for each individual: Sex, life-history stage, external diseases, parasites, and other abnormalities. When the number of individuals of a species in a sample exceeded 100, 50 or more individuals were weighed and measured; the remaining fish were counted and an aggregate weight was taken. All information was recorded on computer data forms. Hart (1973) was used as a reference for identification of the fishes.

Fish to be used for stomach analysis were dissected; the stomach was removed, tagged, and preserved in 10 percent formalin. In those fish without well-defined stomachs, the first one-third of the intestine was removed and preserved.

II-F. Sources of Sampling Error

A major source of sampling error was gear selectivity. Each gear type possessed its own selectivity which must be taken into account when comparing results of different gear types. Sample variation also resulted from bottom conditions, weather conditions, light intensity (diurnal-nocturnal), sea conditions, bioluminescence, turbidity, and sampling duration.

Because the large mesh wings of the townet and beach seine were not as effective in retaining larvae and small juveniles as the bag, quantitative results concerning small fish are likely to include underestimates. Certain fast-swimming and fast-reacting species probably were able to avoid the sampling gear.

The topography of the substrate affected the performance of the beach seine. Smooth substrates were swept more efficiently than uneven substrates. Furthermore, large quantities of algae or eelgrass reduced sampling efficiency.

The Jamestown site presented significant obstacles to the beach seine sampling scheme. At a zero or minus tide, less than 30 cm of water covered the mud/eelgrass flat. During spring and summer sampling periods the customary two sets were made although the seine skiff could not be rowed due to the shallow depth of the water. Consequently, the skiff was towed by a crew member wading through the water. During fall and winter no sets were attempted due to the extreme shallowness of the water.

Sample bias was also introduced by the crew during the picking of the net. Transparent larvae and small fish may have been overlooked, particularly when sampling was conducted at night in inclement weather. Inclement weather also affected gear performance.

Beach seining was conducted on the lowest tides of the sampling period. During October through January, sampling occurred at night whereas in May through August it occurred during day. Comparison of these two periods must take into consideration potential diel changes in the fish fauna.

Bias also occurred in sampling the macroinvertebrates collected with the fish. The more fish and algae present in the net, the less efficient was the invertebrate sampling effort due to the difficulty in finding invertebrates among the algae and also to time constraints involved in setting and retrieving the net.

II-G. Disposition of Data

All data were initially recorded on computer sheets formated according to MESA/EDS specification. Codes utilized in data recording were developed by NODC. The data were then checked for errors, keypunched on 80-column IBM cards, and verified. All data cards were systematically organized and transferred onto magnetic tape.

II-H. Trophic Diagrams

In the presentation of the food habit data, a modification of Pinkas et al. (1971), "Index of Relative Importance" (IRI) has been utilized where sample sizes justify its use ($n \geq 25$). This three-way graphical method illustrates frequency of occurrence (that proportion of stomachs containing a specific prey organism) plotted on the horizontal axis and percentage of total abundance and percentage of total biomass plotted for each prey item above and below the horizontal axis, respectively. The prey have been organized from left to right by decreasing frequency of occurrence; items of taxa with less than 5 percent frequency of occurrence or 1 percent of total abundance or biomass were not graphed. Prey items that occurred in more than 5 percent of the stomachs appear on the graph, but if either the abundance or biomass of a particular item was less than 1 percent of the total, a bar was not drawn. Hence, if a prey taxon appears on the graph but no bars extend above or below the horizontal axis, that particular taxon was present in more than 5 percent of the stomachs but contributed less than 1 percent to abundance (above) and biomass (below).

III. RESULTS AND DISCUSSION

To facilitate presentation of the results, sites have been grouped into western sites (Kydaka Beach, Pillar Point, Twin Rivers, Morse Creek) and eastern sites (Dungeness Spit, Jamestown, Beckett Point). This division is artificial in that it arbitrarily relegates similar sites to one of the two general regions; on the other hand, the data suggest that some oceanographic and faunal differences exist between these two regions.

III-A. Oceanographic Conditions

Data on temperature, salinity, and dissolved oxygen measured during beach seine and townet collections are presented in Appendix 1. Values measured were not unusual and did not appear to play a determining role in fish distribution.

III-B. Species Richness

A total of 76 species was collected during the sampling period (Appendix 2); 69 were collected in the beach seine and 48 were collected in the townet.

III-B-1. Beach Seine

Species richness (defined as the total number of species collected) was maximum during summer or fall (Fig. 2, Appendix 3-a).[1] Minimum values occurred in winter and spring.

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[1]Appendix 3-a shows the combined results of the floating and sinking sets at Beckett Point, while Fig. 2 shows only the floating sets since sinking sets were completed in spring and winter only.

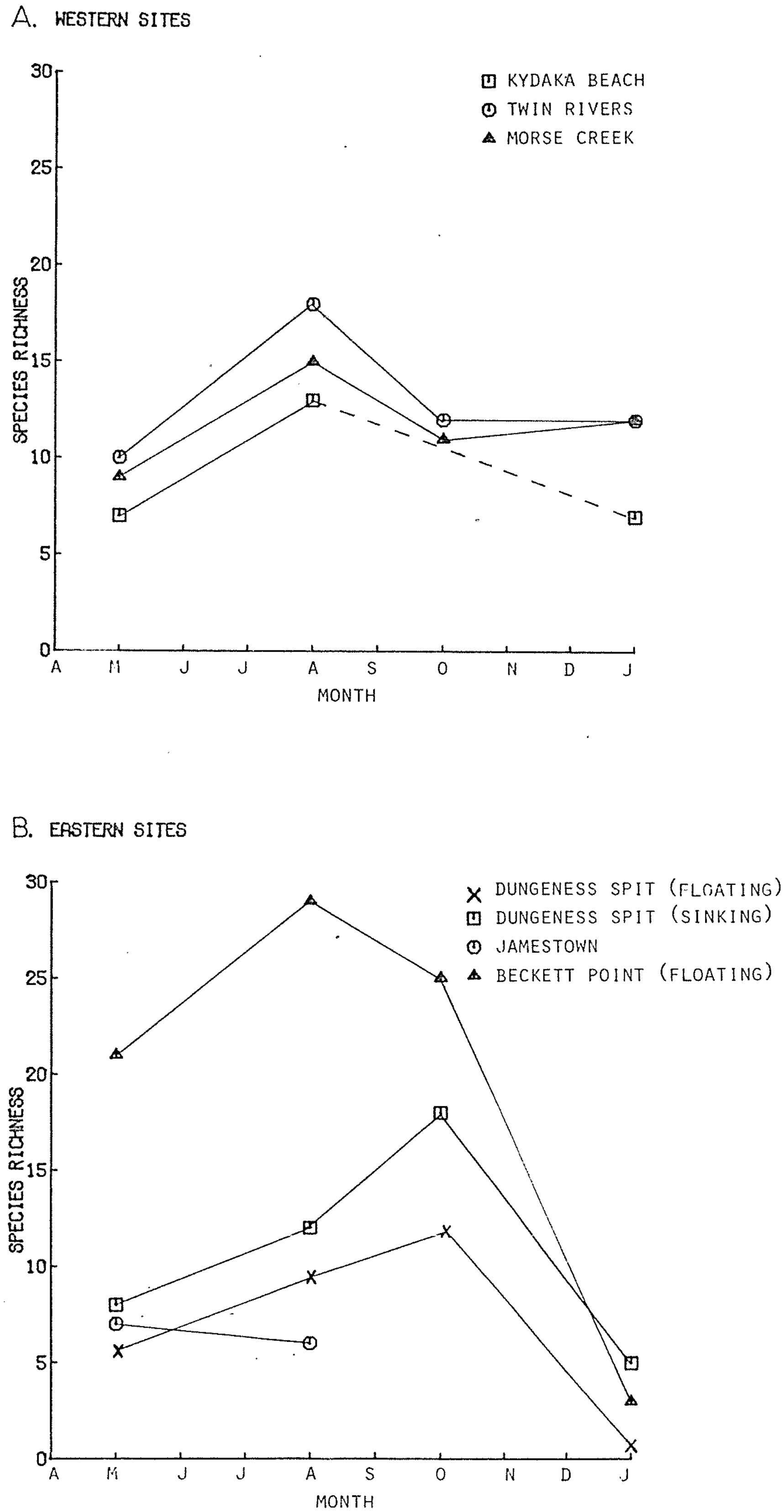


Fig. 2 Species richness (number of species) of nearshore fish for western sites (A) and eastern sites (B) from quarterly beach seine collections in the Strait of Juan de Fuca.

Species richness was generally comparable at all sites except Beckett Point. Values at Beckett Point (in Discovery Bay) were up to two times greater than all other sites throughout the year. This may be due to: 1) The use of Discovery Bay as a nursery area by many species; and 2) the close proximity of the mud/eelgrass habitat to a steep sand slope which drops off into deep water (> 20m).

Species richness generally increased from west to east (Fig. 3). (Values for floating and sinking sets at Dungeness Spit and Beckett Point were combined to facilitate comparisons with the remaining sites.) The low value for Jamestown is not strictly comparable to the values recorded for the remaining sites. At low slack tide, less than 30 cm of water covered the mud/eelgrass flat. The beach seine did not work properly at that depth. Also, large fish present on the mud flat at high tide had moved out into deeper water by low slack water. (Cross, personal observation).

Species richness values for the Strait of Juan de Fuca were generally comparable to values recorded in north Puget Sound (Miller et al. 1977) in both magnitude and seasonal trends; the highest value for both areas occurred at Beckett Point.

III-B-2. Townet

Species richness is plotted against season (Fig. 4) and summarized by site (Appendix 4-a). Maximum species richness generally occurred from spring through autumn while minimum richness occurred in the winter. Sites collected by townet in north Puget Sound exhibited similar trends in species richness (Miller et al. 1977).

No consistent seasonal trends based on habitat, exposure, geographical area, or other physical factors were evident. Similar results were reported for north Puget Sound (Miller et al. 1977).

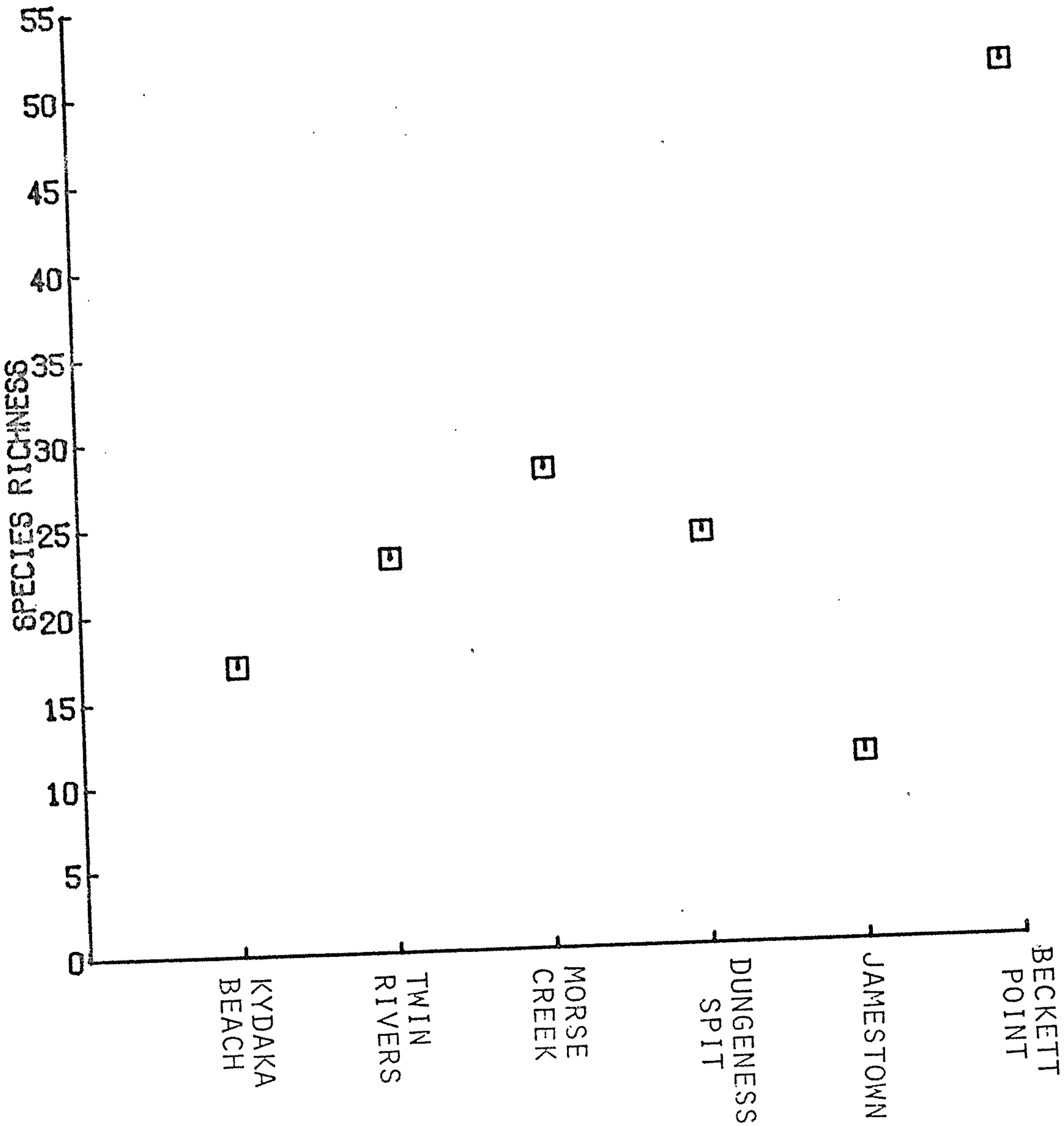


Fig. 3. Total number of species caught by beach seine at each site throughout the first sampling year.

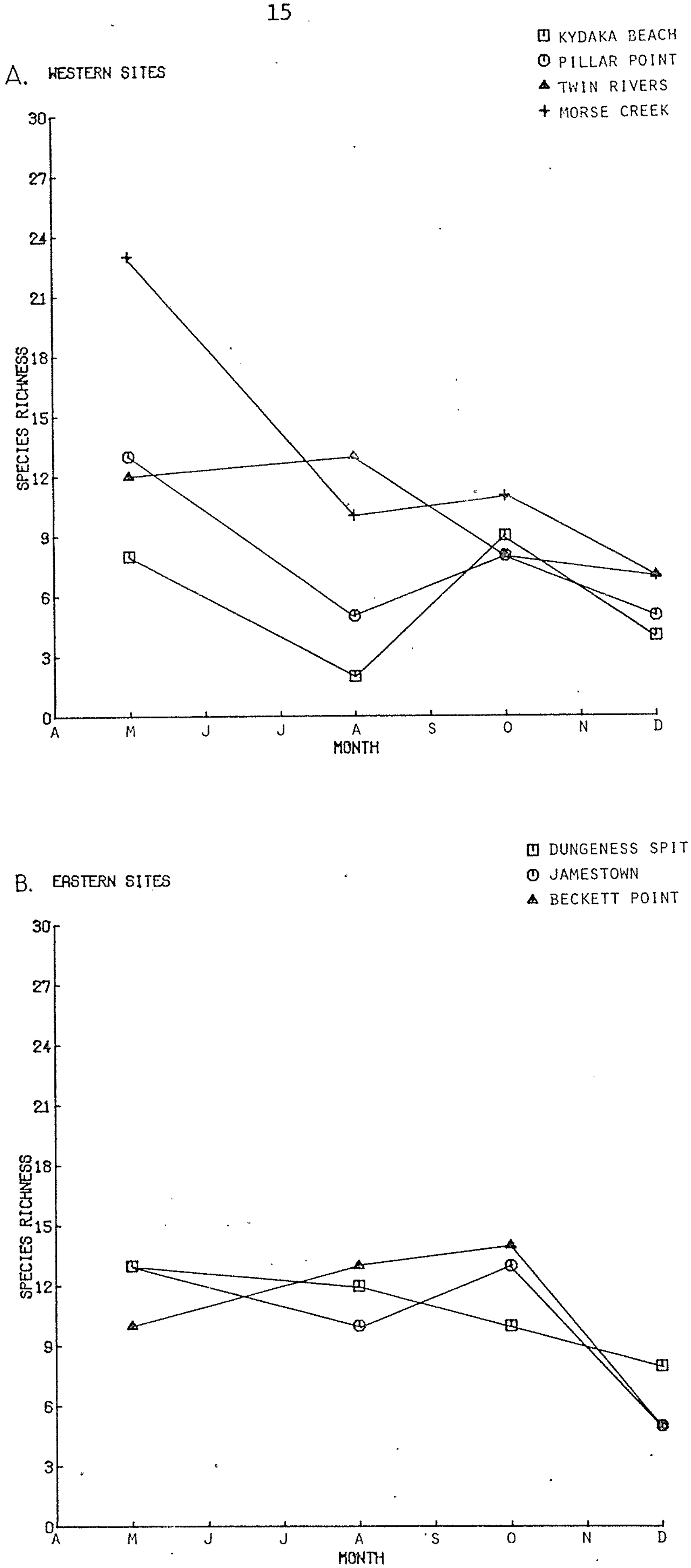


Fig. 4. Species richness (number of species) of nearshore fish, for western sites (A) and eastern sites (B), from quarterly tow-net collections in the Strait of Juan de Fuca.

Species richness clearly exhibited a general increasing trend from west to east (Fig. 5). However, further data is necessary before attempting to explain this trend.

Spring levels of richness were principally due to the occurrence of the larvae of a number of species which are demersal as adults. Catches of these larvae were small (usually ≤ 5 per tow) and varied in species composition from site to site.

III-C. Density

III-C-1. Beach Seine

Raw abundance values were transformed to density values (fish/m^2) (Appendix 3-b) by dividing by 920 m^2, the area swept by the beach seine.

At all sites except Beckett Point, the density of fish was maximum during the summer and minimum throughout the rest of the year (Fig. 6). Maximum values for all sites and all collections were obtained during the summer at Dungeness Spit and Kydaka Beach. This was due to large schools of Pacific sand lance (*Ammorodytes hexapterus*) at Dungeness and Pacific herring (*Clupea harengus pallasi*) at Kydaka.

Beckett Point exhibited an increase in fish density from spring to winter. The high value in autumn was due to schools of shiner perch (*Cymatogaster aggregata*). The highest value, obtained in winter, was due to schools of tube-snout (*Aulorhynchus flavidus*) and shiner perch.

Minimum values were recorded during the winter at the most exposed sites (Kydaka Beach and Dungeness Spit), during the spring at the moderately exposed sites (Twin Rivers and Morse Creek), and during spring at the most protected site (Beckett Point).

Both the densities of fish and seasonal trends in density fluctuations were generally comparable between the Strait of Juan de Fuca and

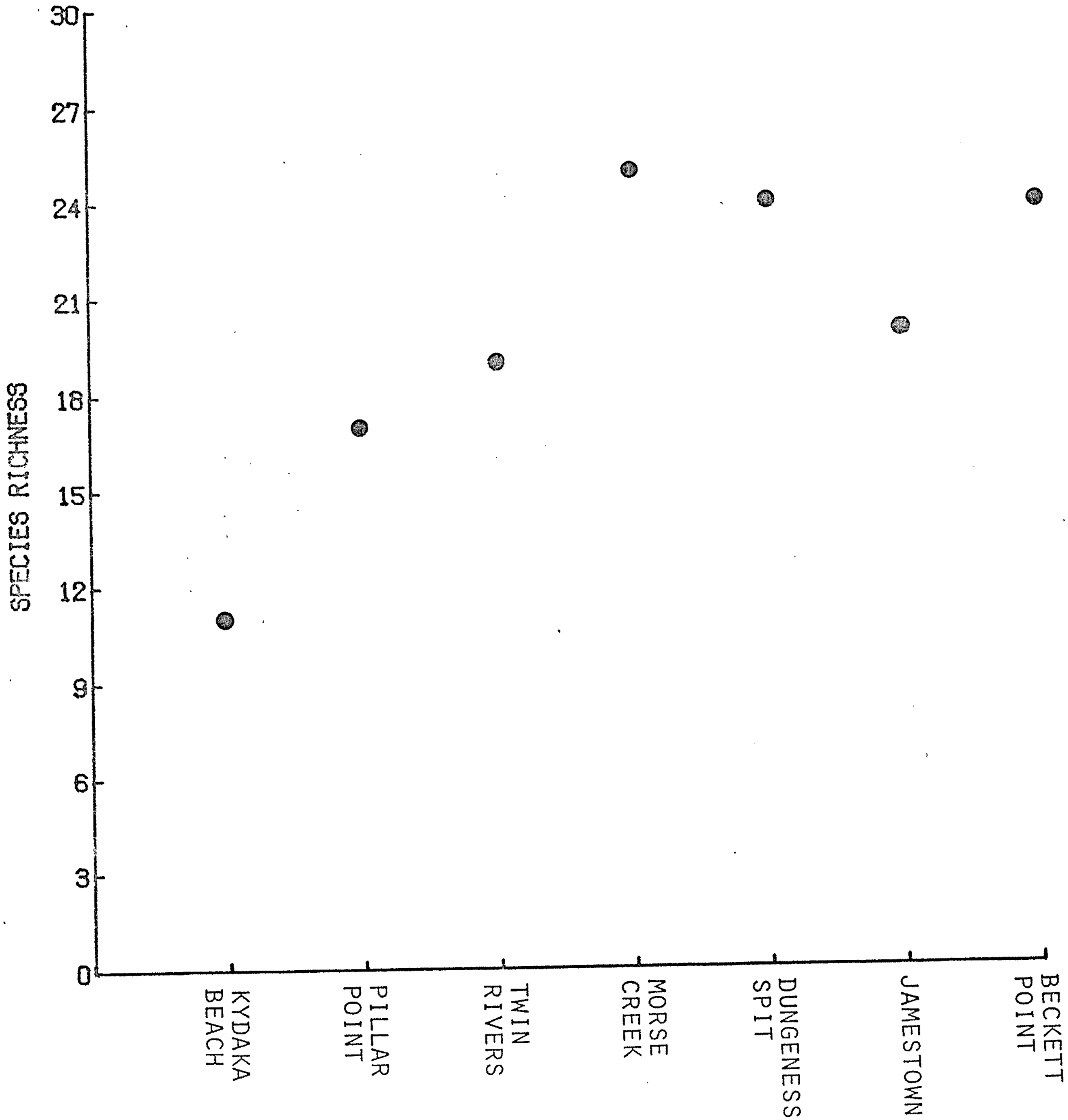


Fig. 5. Total number of species caught by the townet at each site throughout the first sampling year.

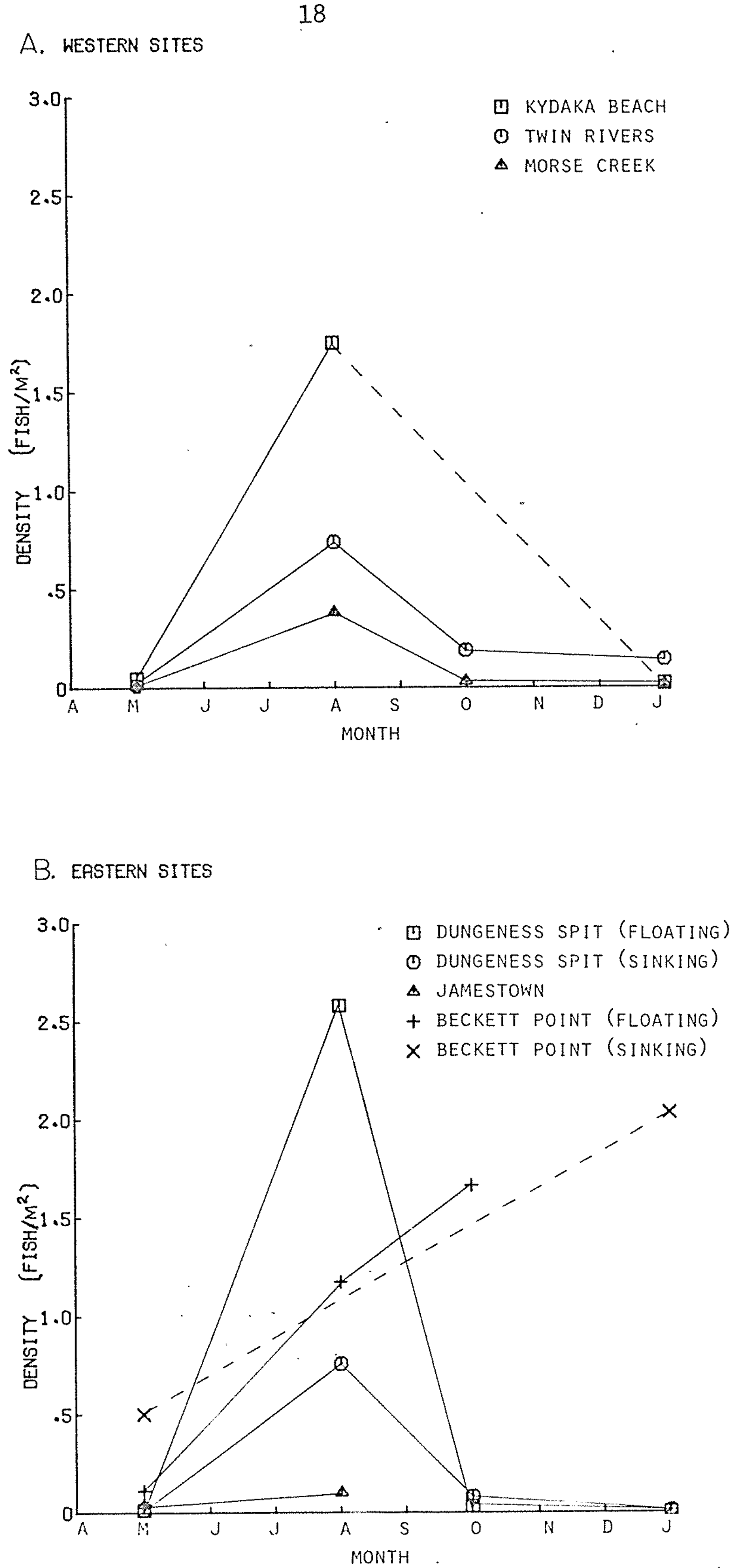


Fig. 6. Mean density (fish/m^2) of nearshore fish for western sites (A) and eastern sites (B) from quarterly beach seine collections in the Strait of Juan de Fuca.

north Puget Sound (Miller et al. 1977). In north Puget Sound a spring peak, in addition to a summer-fall peak, was noted; this spring increase was not evident in the Strait collections. In the Puget Sound, the highest densities were recorded in gravel habitat, while the highest densities in the Strait of Juan de Fuca were recorded at exposed sand beaches.

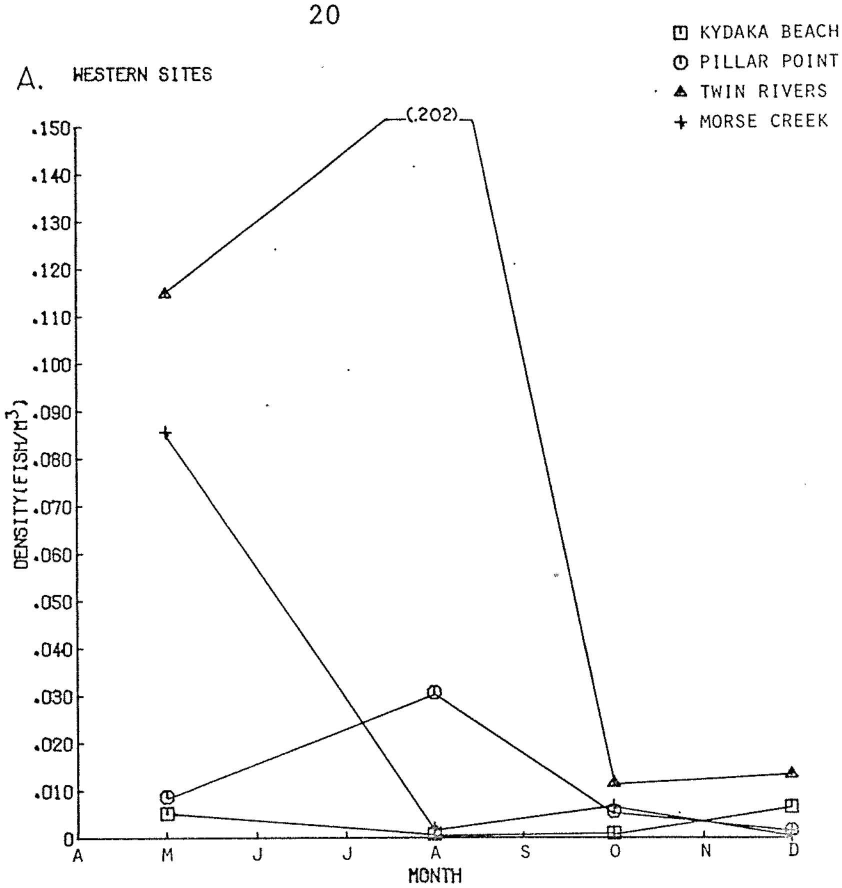
III-C-2. Townet

Raw abundance values were converted to density by dividing by 11,500 m^3, the volume of water strained during an average 10-minute tow (Appendix 4-b).

Maximum and minimum densities and seasonal trends indicate three general patterns. Although unrelated by habitat, density trends at Pillar Point, Dungeness Spit, and Beckett Point were similar (Fig. 7). Density increased from spring to summer and decreased from summer to winter. Maximum densities occurred in the summer, primarily as a result of juvenile Pacific herring at Dungeness Spit and Beckett Point, and longfin smelt (*Spirinchus thaleichthys*) at Pillar Point. Minimum densities occurred during the winter. The seasonal trend at Twin Rivers was very similar to the preceding sites except the minimum occurred in autumn. The difference between autumn and winter values was small enough (0.0019 fish/m^3) probably to be insignificant; as a result, this site probably could be grouped with Pillar Point, Dungeness Spit, and Beckett Point.

Density at Morse Creek exhibited its own characteristic pattern, decreasing from the maximum level in the spring to values less than 0.01 fish/m^3 throughout the rest of the year (Fig. 7). High spring density was due to larvae of several species, notably Pacific herring and walleye pollock (*Theregra chalcogramma*).

Densities at Jamestown and Kydaka Beach were low throughout the year (Fig. 7). Only on one occasion (Jamestone in spring) did values at



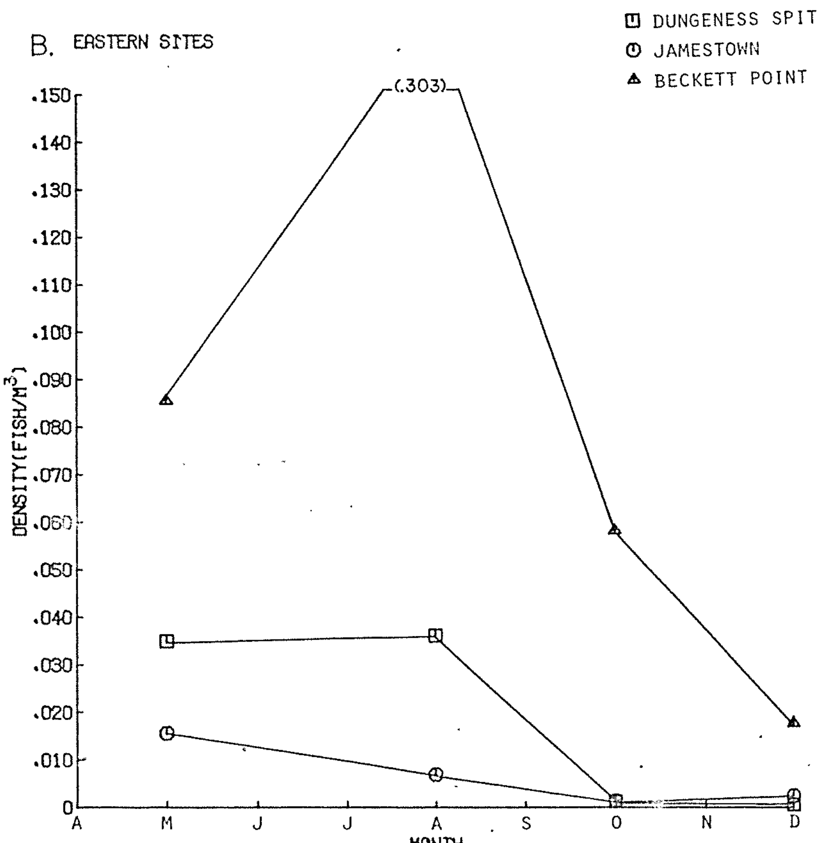


Fig. 7. Mean density (fish/m^3) of nearshore fish, for western sites (A) and eastern sites (B), from quarterly townet collections in the Strait of Juan de Fuca.

these sites increase above 0.0068 fish/m^3. The low densities at Kydaka Beach are probably attributable to direct exposure to wave surge and an unstable sand substrate. While lacking substantive data, it seems likely that the low densities at Jamestown were due to high daily fluctuations in temperature, salinity, and dissolved oxygen which probably occurred because of the extreme shallowness of the eelgrass-choked water. These fluctuations would tend to exclude all but the most tolerant and adaptable species. The substantial difference in density observed between the two protected sites (Beckett Point and Jamestown) may also be a function of the shallowness of the Jamestown site.

The greatest variability in density occurred at sites that were the least physically stressed (e.g., Beckett Point) while the least variability was characteristic of sites that were the most physically stressed (e.g., Kydaka Beach and Jamestown).

Densities of fish from townet samples at comparable sites in the Strait and north Puget Sound (Miller et al. 1977) were very similar. Protected north Puget Sound eelgrass sites (e.g., Westcott Bay, Birch Bay, and Lummi Bay) had mean densities ranging between 0.105 and 0.324 fish/m^3. This was very close to the mean density observed at one of our protected eelgrass sites (Beckett Point). Jamestown, as noted previously, was not comparable because of its extreme shallowness. More exposed sites in north Puget Sound (e.g., South Beach and Guemes Island south) and in the Strait (Kydaka Beach and Pillar Point) were also very similar (mean density $\leq$ 0.01 fish/m^3 in both areas). The greatest seasonal variations were observed in both areas at the most protected sites, while the least variation was characteristic of the least protected.

III-D. Standing Crop

III-D-1. Beach Seine

Raw biomass values were transformed to standing crop (grams/m2) (Appendix 3-c) by dividing the weight of the catch by 920 m^2.

Standing crop reached its maximum value at different times of the year at different sites (Fig. 8). At the more protected sites (Twin Rivers, Morse Creek, and Beckett Point), maximum values were recorded in autumn. High values at Twin Rivers and Morse Creek were due primarily to the redtail perch (*Amphisticus rhodoterus*). Shiner perch, staghorn sculpin (*Leptocottus armatus*), and starry flounder (*Platichthys stellatus*) accounted for the high value at Beckett Point. Maximum standing crop occurred at Dungeness Spit in summer due to the presence of sand lance schools, adult spiny dogfish (*Squalus acanthias*) and adult chinook salmon (*Oncorhynchus tshawytscha*). Unfortunately, data for Kydaka Beach for autumn were not gathered due to inclement weather, so a correlation between the most exposed sites cannot be made. Minimum standing crop values occurred in spring and winter at all sites except Twin Rivers and Beckett Point.

Wide variation (SD; Standard Deviation) in standing crop was apparent in each quarter, but was particularly conspicuous in autumn and winter when biomass values for Twin Rivers and Beckett Point were an order of magnitude larger than biomass values for most of the other sites (Appendix 3-c).

Standing crop values for the Strait of Juan de Fuca were generally comparable in magnitude and exhibited similar fluctuations to standing crop values for the north Puget Sound (Miller et al. 1977). The highest values for either area were recorded in the north sound in gravel habitat. The highest values in the Strait were recorded in mud/eelgrass and cobble/sand habitats.

III-D-2. Townet

Raw biomass values per 10-minute tow were divided by 11,500 m^3 to convert to standing crop. Standing crop (gram/m^3) was plotted against collection month (Fig. 9) and summarized quarterly and by site (Appendix 4-c).

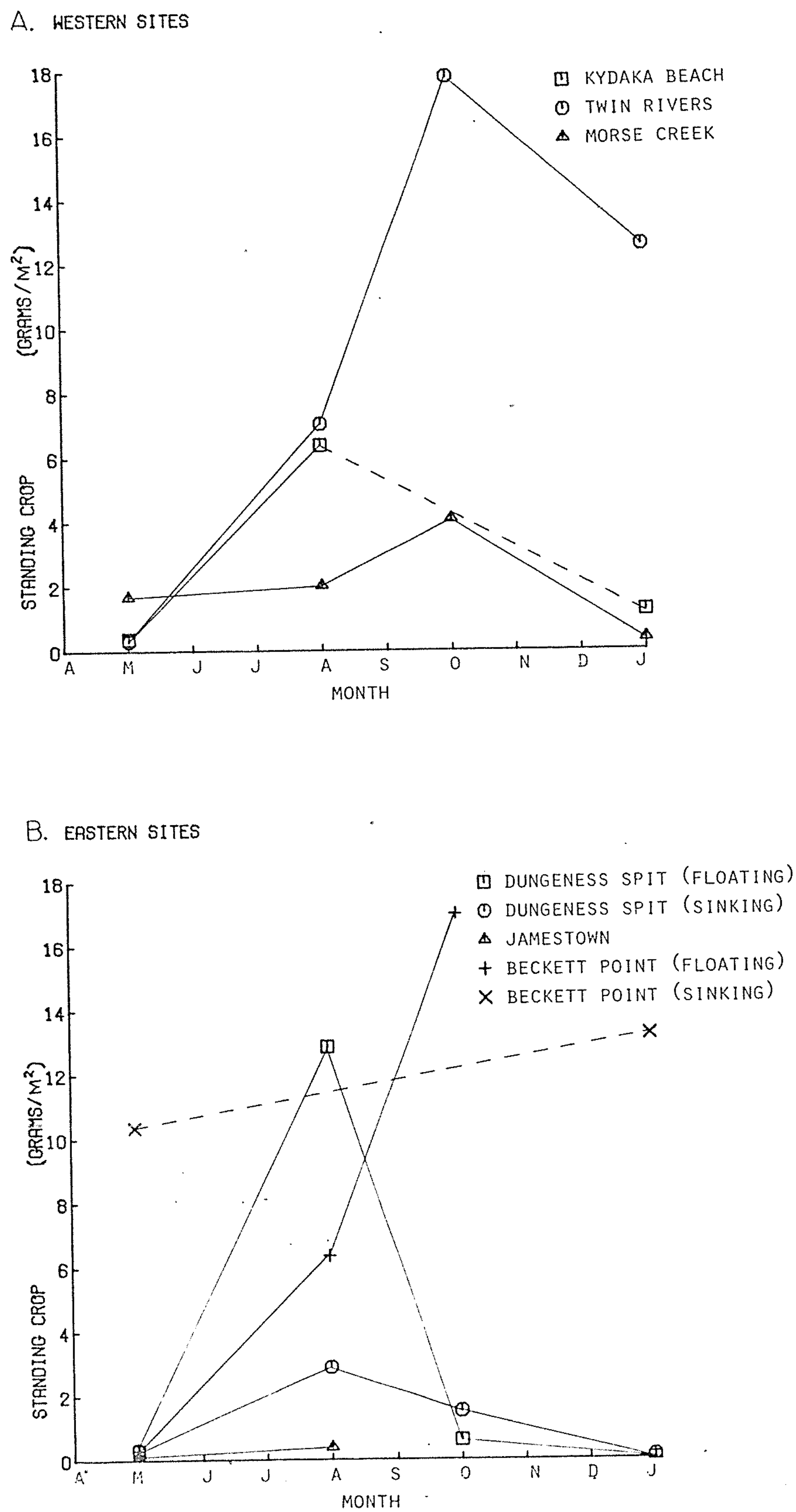


Fig. 8. Mean standing crop (grams/m^2) of nearshore fish for western sites (A) and eastern sites (B) from quarterly beach seine collections in the Strait of Juan de Fuca.

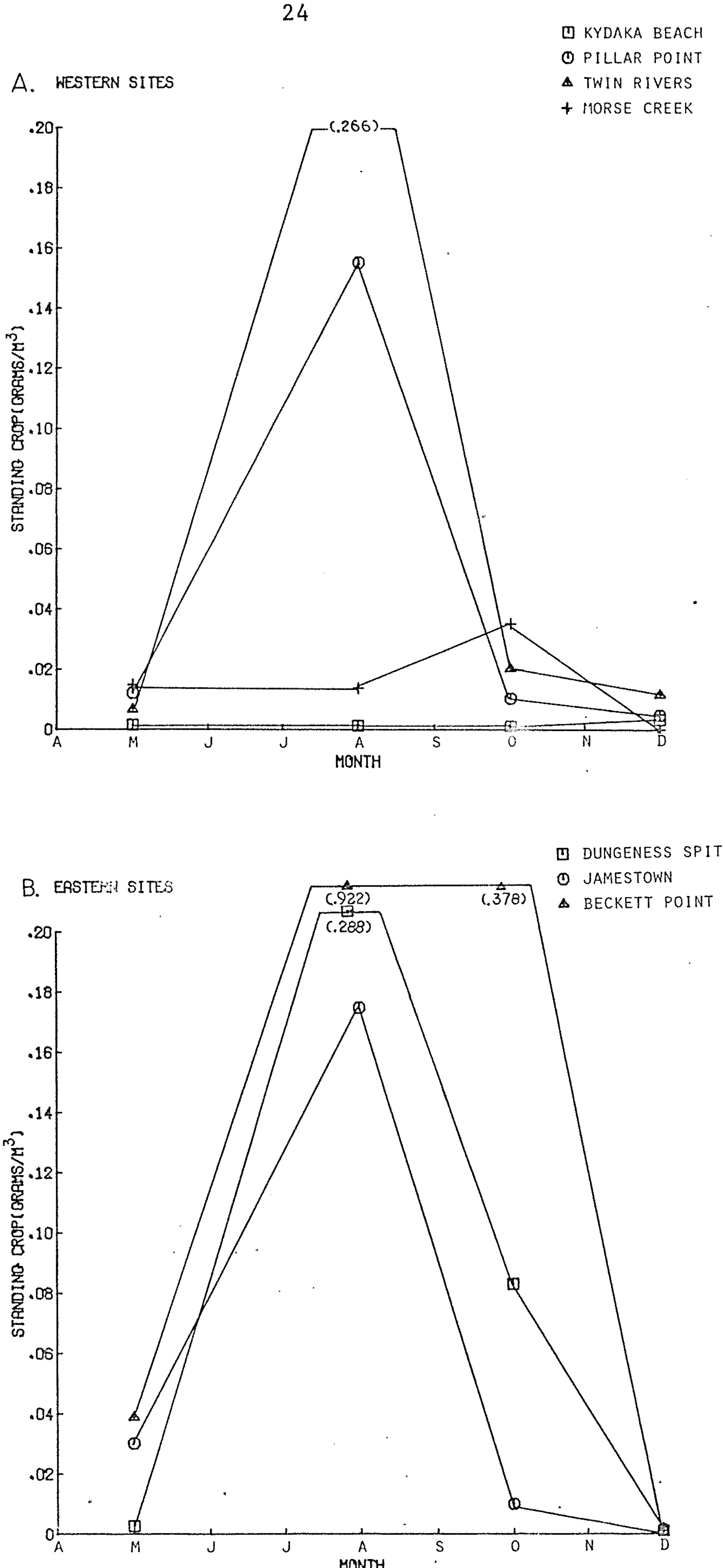


Fig. 9. Mean standing crop (grams/m^3) of nearshore fish, for western sites (A) and eastern sites (B), from quarterly townet collections in the Strait of Juan de Fuca.

With the exception of Morse Creek and Kydaka Beach, all sites followed the same pattern in standing crop. A substantial increase occurred from spring to summer, followed by a steady decline from summer to winter. Maximum biomass occurred in the summer. These maxima were due primarily to Pacific herring at Twin Rivers and Beckett Point, longfin smelt at Pillar Point, and adult spiny dogfish at Dungeness Spit at Jamestown.

Standing crop at Morse Creek increased from spring to an autumn maximum and then declined to a winter low. The autumn maximum was due to juvenile Pacific herring and juvenile pink salmon (*Oncorhynchus gorbuscha*).

Standing crop at Kydaka Beach did not vary greatly during the year; this was probably because of the extreme exposure.

With the exception of Kydaka Beach, the general seasonal trend in standing crop observed in the Strait was similar to that observed in north Puget Sound (Miller et al. 1977). Maxima, while typically greater in the north Sound, occurred in both areas in the summer and fall, while minima were characteristic of spring and winter. The greatest amount of seasonal variation in both areas occurred in the most protected sites while the least variation occurred at the most exposed sites. Mean standing crop at the most protected sites in both areas ranged from 0.20 to 0.69 fish/m^3, while at the most exposed sites it was typically less than 0.1 fish/m^3.

III-E. Dominant Nearshore Fish Species

III-E-1. Beach Seine

Three species occurred in sufficient numbers at all or most sites to allow for analysis of their distribution and abundance (Appendix 5). The sand sole (*Psettichthys melanostictus*) occurred most abundantly at exposed sites (Kydaka Beach and Dungeness Spit) in summer and at a moderately exposed site (Twin Rivers) in winter. High biomass at Twin Rivers in summer and winter was due to the large size of adults captured.

The English sole was most abundant at moderately exposed sites (Twin Rivers and Morse Creek) and at a protected site (Jamestown in summer. Biomass was high at these sites in summer. Maximum biomass was recorded at Beckett Point in winter owing to the large number of adults captured.

The staghorn sculpin was abundant throughout the year at the most protected site, Beckett Point; it was also abundant in the two collections made at Jamestown. It was abundant at Beckett Point throughout the year. Maximum biomass occurred at Beckett Point in autumn. High biomass values were also recorded at Twin Rivers in summer and winter and at Kydaka Beach in winter because of the large size of adults collected.

III-E-2. Townet

Four species (Pacific herring, longfin smelt, walleye pollock, and shiner perch), accounting for 91.8 percent of the fish caught, dominated the catches (Appendix 5). Pacific herring, the most abundant, occurred in 26 out of 28 collections and accounted for 69.1 percent of the total abundance and 35.0 percent of the total biomass; it was clearly the dominant neritic species in the collections. The relative abundance and biomass of Pacific herring were plotted by collection at all sites.

Herring occurred predominantly as larvae in the spring and as juveniles throughout the rest of the year. No adult herring were caught. While occurring at all sites, herring were most abundant at Twin Rivers and Beckett Point. Herring appeared to move out of the immediate near-shore surface waters during the winter; less than 1 percent of the total numbers caught occurred in winter collections.

After herring, the next most abundant species was longfin smelt. Longfin smelt accounted for 12.4 percent of the total numbers of fish and 5 percent of the total biomass, but occurred in only 11 of 28 collections. The presence of both larvae and ripe adults in our catches indicated that the anadromous longfin smelt spawned in streams discharging into the Strait of Juan de Fuca.

As 99.8 percent of the longfin smelt were caught west of Port Angeles, this species appears to be largely limited to the western Strait. While the reason for this limitation cannot be determined precisely, it seems likely to be a function of availability of spawning streams.

Larval and juvenile walleye pollock and juvenile and adult shiner perch were the next most abundant species. Walleye pollock were caught in 12 of 28 collections and accounted for 5.1 percent and 1.1 percent of the total abundance and biomass, respectively. Although pollock occurred at all sites, they were caught almost exclusively in spring and summer. Shiner perch occurred in only seven of the 28 collections and accounted for 5.2 percent of the total numbers and 1.7 percent of the total biomass. Shiner perch occurred at four sites but over 99 percent were caught at Beckett Point. This seems to indicate a preference for a more protected habitat.

III-F. Species Assemblages

A major objective of the study was to determine whether characteristic, habitat-associated fish assemblages occur in the nearshore pelagic and demersal environment in the Strait of Juan de Fuca.

From the limited data available, the nearshore neritic and demersal fish fauna along the Strait of Juan de Fuca exhibit a variety of overlapping distributions based upon habitat, geographic location, exposure to open coast conditions, and other yet undetermined factors. Further data are required before a quantitative species assemblage analysis can be undertaken but some preliminary observations on the commonly occurring species are presented.

Staghorn sculpin and herring were collected at all sites along the Strait of Juan de Fuca. Longfin smelt occurred in the western part of the Strait in all habitats. Walleye pollock, tomcod, and juvenile salmonids occurred in the eastern part of the Strait in all habitats. Sand sole were common at the more exposed sites (Kydaka Beach and Dungeness Spit); English sole were common at moderately exposed sites (Twin Rivers and Morse Creek). Shiner perch occurred abundantly only at Beckett Point. Redtail surfperch occurred abundantly only at Twin Rivers.

III-G. Macroinvertebrates

III-G-1. Species Composition

A total of 115 macroinvertebrate species were identified from the nearshore fish collections (Appendix 6). Decapod and amphipod crustaceans constituted the most common, most diverse taxa collected, followed by mysids, isopods, euphausids, polychaetes, mollusca, and other less common organisms. Raw abundance data for the macroinvertebrates catalogued are included in Appendix 7.

The beach seine collected 81 species; the townet 51. Beach seine collections were typically demersal and shallow epibenthic organisms, while the townet included pelagic as well as epibenthic invertebrates. Euphausids were collected only by the townet (almost exclusively at Pillar Point). Nudibranchs, bivalves, univalves, echinoderms, and caprellid amphipods were collected only by beach seine. The majority of the crab species (13/15) were taken only by beach seine. Two species of *Pugettia* were taken by both net types. Often, however, species taken by both net types were not collected at the same locations (e.g., *Acanthomysis davisi* was taken only at Twin Rivers by townet and only at Morse Creek by beach seine).

Errantiate polychaete worms were collected by beach seine and townet, although *Platynereis bicanaliculata* was the only species taken by both.

The parasitic isopod, *Argeia pugettensis*, was found parasitizing *Crangon stylirostris*.

III-G-2. Species Richness

Total species richness generally increased from the western sites to the eastern sites (Tables 2 and 3). Seasonal values showed minima usually occurring in fall and maxima in spring.

III-G-3. Abundance and Standing Crop

Although the data should not be considered quantitative, they suggest that the numbers of epibenthic macroinvertebrates (captured by beach seine) reach a peak in summer and that the standing crop (biomass per standard sample) may be higher in the more protected sampling sites (Appendix 6). Similarly, neritic macroinvertebrates tended to show the highest densities in winter and spring, although the biomass typically increased from spring minima to higher values in winter.

III-G-4. Size Frequencies of Dominant Species

Size frequency distributions were plotted for 18 common species, pooled by season of collection (Appendix 8). As illustrated, most of the common epibenthic and pelagic macroinvertebrates available to our sampling gear were crustaceans in the 4- to 20-mm length range except for Dungeness crabs, which were ≤ 150 mm in carapace width. The appearance and growth of age classes of several species, including *Crangon stylirostris*, *C. nigricauda*, *Eualus fabricii*, and *Atylus tridens*, are also suggested (Appendix 8).

III-H. Nearshore Fish Food Web

Over 1,500 specimens of 61 species of nearshore fishes collected along the Strait of Juan de Fuca were examined for stomach contents (Table 4). For sample sizes exceeding 25 individuals, a species prey

Table 2. Total number of macroinvertebrate species, according to general taxonomic grouping, collected during nearshore fish sampling at seven sites along the Strait of Juan de Fuca, May 1976 - January 1977.

Site	Shrimps	Isopods/ amphipods	Mysids/ euphausids	Misc. groups	Total no. of species	% Total species
Kydaka Point	3	8	4	4	19	16
Pillar Point	0	0	10	6	16	13
Twin Rivers	11	9	11	4	35	30
Morse Creek	10	14	8	7	39	34
Dungeness Spit	10	20	8	10	48	41
Jamestown	17	11	5	16	49	42
Beckett Point	14	11	0	30	55	47

Table 3. Number of macroinvertebrate species collected seasonally during nearshore fish sampling at seven sites along the Strait of Juan de Fuca, May 1976 - January 1977. BS = beach seine, TN = townet, NS = no sampling.

Site	Spring (May)		Summer (August)		Fall (October)		Winter (Dec-Jan)	
	BS	TN	BS	TN	BS	TN	BS	TN
Pillar Point[1]		15		7		NS		NS
Kydaka Point	3	NS	3	NS	NS	NS	6	12
Twin Rivers	7	5	10	8	1	NS	5	17
Morse Creek	15	11	10	4	6	NS	11	13
Dungeness Spit	12	11	13	17	9	NS	10	23
Jamestown	19	8	8	10	NS	16	NS	8
Beckett Point	35	5	15	1	7	NS	22	NS

[1]Beach seining was not conducted at Pillar Point.

Table 4. Nearshore fishes analyzed for stomach contents, Strait of Juan de Fuca, July 1976-January 1977.

Species	Total sample size n	% Empty stomachs	Fullness factor $\bar{x}$±S.D.	Digestion factor $\bar{x}$ ± S.D.	Prey abundance $\bar{x}$ ± S.D.	Prey biomass $\bar{x}$ ± S.D.	Shannon-Weiner diversity index H' Abundance	Shannon-Weiner diversity index H' Biomass
Squalus acanthias, spiny dogfish (subadult)	5	0	3.2±0.4	3.8±0.4	2.4±2.1	2.58±2.89	2.75	2.38
Raja binoculata, big skate (juvenile)	1	0	4.0	5.0	42.0	1.66	1.72	1.46
R. abyssicola (adult)	1	0	5.0	4.0	13.0	18.22	1.00	0.73
R. stellulata, starry skate (adult)	2	0	4.5±0.7	4.0±0.0	28.0±0	14.12±5.81	2.97	2.93
Clupea harengus pallasi, Pacific herring (juvenile)	114	42	2.4±1.4	2.5±1.6	81.1±152.2	0.03±0.06	0.66	1.33
Engraulis mordax, northern anchovy (8 adults; 4 juveniles)	12	8	3.4±1.2	3.2±1.1	25.6±55.3	0.09±0.14	1.14	1.71
Oncorhynchus gorbuscha, pink salmon (juvenile)	48	25	3.3±1.4	2.9±1.4	193.5±265.5	0.22±0.28	1.44	1.77
O. keta, chum salmon (juvs.)	17	0	5.3±1.1	4.6±0.7	54.4±31.9	0.04±0.7	1.84	2.33
O. kisutch, coho salmon (juvenile)	4	25	4.3±2.4	4.0±2.0	43.8±32.6	0.27±2.3	1.01	0.66
O. tshawytscha, chinook salmon (juvenile)	11	0	4.0±0.9	3.6±0.8	42.4±100.9	0.44±0.42	1.99	2.38
Salmo gairdneri, rainbow (steelhead) trout (adult)	2	50	3.0±2.8	2.0±1.4	34.5±48.8	0.68±0.95	0.0	0.0
Hypomesus pretiosus, surf smelt (39 adults, 27 juveniles)	66	51	2.3±1.5	2.3±1.5	84.8±213.0	0.05±0.12	0.57	1.24
Spirinchus thaleichthys, longfin smelt (33 adults, 13 juveniles)	46	58	2.0±1.4	2.2±1.7	20.5±64.0	0.04±0.10	2.13	2.89
Porichthys notatus, plainfin midshipman (adult)	1	0	5.0	5.0	2.0	2.75	1.00	0.99
Gobiesox maeandricus, northern clingfish (postlarval)	2	0	1.0±0.0	1.0±0.0	0	0.01±0.0	0.0	0.0
Gadus macrocephalus, Pacific cod (juvenile)	2	0	4.0±2.8	3.5±2.1	6.5±7.8	0.46±0.52	1.15	1.15
Microgadus proximus, Pacific tomcod (18 adults, 53 juveniles)	80	3	3.7±1.3	3.8±1.3	17.6±32.4	0.30±0.67	3.58	3.45

Table 4. Nearshore fishes analyzed for stomach contents, Strait of Juan de Fuca, July 1976–January 1977.

Species	Total sample size n	% Empty stomachs	Fullness factor x±S.D.	Digestion factor x ± S.D.	Prey abundance x ± S.D.	Prey biomass x ± S.D.	Shannon-Weiner diversity index H' Abundance	Shannon-Weiner diversity index H' Biomass
Theragra chalcogramma, walleye pollock (1 adult, 50 juvs.)	51	1	3.9±1.1	4.0±1.2	66.7±134.9	0.15±0.53	0.72	3.11
Gasterosteus aculeatus, threespine stickleback (adult)	14	28	4.1±1.9	3.6±1.4	54.9±55.1	0.01±0.01	1.04	1.57
Aulorhynchus flavidus, tube-snout (40 adults, 8 juvs., 15 unstaged)	63	38	2.3±1.6	2.7±2.0	13.8±26.6	0.01±0.03	2.49	2.27
Syngnathus griseolineatus, bay pipe-fish (5 adults, 2 juveniles)	7	0	4.1±1.5	3.3±1.7	5.4±6.2	0.03±0.03	0.85	1.49
Sebastes sp., rockfish species (post-larval)	2	0	2.5±3.5	4.0±1.4	1.5±2.1	0.92±0.42	0.0	0.0
Hexagrammos stelleri, whitespotted greenling (1 adult, 4 juvs.)	15	0	4.9±1.0	3.6±0.8	17.7±15.8	0.76±1.05	3.54	2.77
Ophiodon elongatus, lingcod (juvenile)	1	0	4.0	4.0	1.0	0.67	0.0	0.0
Artedius fenestralis, padded sculpin (8 adult, 13 juvs., 5 unstaged)	26	3	4.7±1.4	3.9±1.5	8.6±9.8	0.13±0.24	2.80	3.05
Ascelichthys rhodorus, rosylip sculpin (5 adult, 6 juv., 6 unstaged)	17	0	4.7±1.0	3.6±1.1	17.4±22.3	0.27±0.31	2.46	3.23
Blepsias cirrhosus, silverspotted sculpin (9 adult, 15 juv., 1 postlarval, 16 unstaged)	41	0	4.6±1.2	3.9±1.0	13.5±17.4	0.15±0.14	3.47	3.35
Clinocottus acuticeps, sharpnose sculpin (1 adult, 1 juvenile)	2	0	4.5±3.5	3.0±1.4	140.5±195.9	0.90±1.27	2.08	0.80
Enophrys bison, buffalo sculpin (4 adult, 9 juv., 3 unstaged)	16	25	3.9±2.3	3.8±2.1	11.5±16.9	1.54±2.47	3.60	2.79
Leptocottus armatus, staghorn sculpin (44 adult, 26 juvs, 22 unstaged)	92	8	4.3±1.7	3.5±1.4	83.2±517.4	2.79±4.95	1.14	4.88
Myoxocephalus polyacanthocephalus, great sculpin (1 adult, 12 juveniles, 1 unstaged)	14	7	3.6±1.7	3.5±1.7	26.1±85.8	0.29±0.27	0.95	2.96
Scorpaenichthys marmoratus, cabezon (adult)	2	0	6.0±0.0	4.0±0.0	7.5±0.7	34.3±2.39	2.68	1.60

Table 4. Nearshore fishes analyzed for stomach contents, Strait of Juan de Fuca, July 1976-January 1977.

Species	Total sample size n	% Empty stomachs	Fullness factor $\bar{x}$±S.D.	Digestion factor $\bar{x}$ ± S.D.	Prey abundance $\bar{x}$ ± S.D.	Prey biomass $\bar{x}$ ± S.D.	Shannon-Weiner diversity index H' Abundance	Biomass
Chiotonotus pugetensis, roughback sculpin (18 adult, 17 juveniles)	35	17	3.4±2.0	3.2±1.8	3.8±7.4	0.13±0.28	3.99	3.12
Occella verrucosa, warty poacher (1 adult, 1 juvenile)	2	0	2.5±2.1	2.5±2.1	3.5±4.9	0.05±0.06	0.59	0.10
Pallasina barbata, tubenose poacher (1 adult, 3 juvs., 8 unstaged)	12	16	3.0±1.2	3.0±1.1	7.0±9.5	0.02±0.02	2.18	2.14
Agonus acipenserinus, sturgeon poacher (20 adults, 8 juvs., 2 unstaged)	30	6	3.8±1.6	3.7±1.6	29.3±55.0	0.15±0.14	3.59	4.05
Liparis callyodon, spotted snailfish (adult)	1	0	5.0	4.0	22	0.71	1.21	1.36
L. cyclopus, ribbon snailfish (2 adults, 2 juveniles, 8 unstaged)	12	0	4.3±1.2	4.5±1.0	6.9±6.7	0.09±0.05	2.26	2.25
L. florae, tidepool snailfish (unstaged)	1	0	5.0	5.0	22	0.13	0.90	0.84
L. mucosus, slimy snailfish (adult)	13	0	5.2±1.1	2.9±1.2	33.5±31.3	0.40±0.26	1.80	1.22
L. pulchellus, showy snailfish (4 juveniles, 1 unstaged)	5	0	3.6±0.5	3.6±0.9	8.0±4.2	0.05±0.03	0.55	0.91
Cymatogaster aggregata, shiner perch (25 adult, 34 juvs., 4 unstaged)	63	68	1.8±1.3	1.7±1.2	12.2±35.5	0.04±0.11	2.40	1.97
Embiotoca lateralis, striped seaperch (19 adult, 11 juvenile)	30	33	3.5±2.1	2.6±1.6	60.4±178.7	1.82±3.01	1.14	2.45
Rhacochilus vacca, pile perch (11 adults, 8 juveniles)	19	84	1.6±1.5	1.4±1.0	2.4±6.9	0.24±0.98	2.07	1.77
Amphistichus rhodorus, redtail surfperch (34 adults, 36 juvs. 8 unstaged)	78	0	3.5±1.2	3.7±1.4	42.4±70.4	2.0±3.27	2.92	3.85
Trichodon trichodon, Pacific sandfish (2 adult, 11 juvs.)	3	33	3.0±2.0	3.0±1.7	13.3±21.4	0.20±0.31	0.62	0.86
Lumpenus sagitta, snake prickleback (adult)	3	0	3.0±1.0	3.3±1.2	135.3±115.8	0.16±0.12	2.95	2.25

Table 4. Nearshore fishes analyzed for stomach contents, Strait of Juan de Fuca, July 1976-January 1977.

Species	Total sample size n	% Empty stomachs	Fullness factor $\bar{x}$±S.D.	Digestion factor $\bar{x}$ ± S.D.	Prey abundance $\bar{x}$ ± S.D.	Prey biomass $\bar{x}$ ± S.D.	Shannon-Weiner diversity index H' Abundance	Shannon-Weiner diversity index H' Biomass
Apodichthys flavidus, penpoint gunnel (7 adults, 7 juveniles)	14	14	3.3 1.5	3.4 1.5	23.4 30.0	0.30 0.38	2.55	2.78
Pholis laeta, crescent gunnel (11 adults, 3 juveniles)	14	28	3.7 2.1	3.1 1.4	10.5 14.1	0.06 0.07	1.62	1.46
P. ornata, saddleback gunnel (adults)	5	0	4.8 1.1	3.6 0.5	17.6 8.4	4.39 9.57	2.49	1.02
Ammodytes hexapterus, Pacific sand lance (3 juveniles, 14 unstaged)	17	29	2.6 1.3	2.9 1.5	209.1 262.9	0.08 0.20	0.01	0.94
Citharichthys stigmaeus, speckled sanddab (3 adults, 3 juveniles)	7	29	4.8 1.0	3.0 0.0	16.5 10.6	0.15 0.17	2.49	1.81
C. sordidus, Pacific sanddab (1 adult, 4 juveniles)	5	0	4.2 0.8	4.4 0.9	3.8 3.0	0.09 0.12	1.47	1.91
Eopsetta jordani, petrale sole (juvenile)	1	0	5.0	5.0	4	0.2	0.0	0.0
Isopsetta isolepis, butter sole (juvenile)	7	0	6.0 0.8	5.0 0.8	30.7 19.6	0.56 0.23	1.27	2.29
Lepidopsetta bilineata, rock sole (22 adult, 17 juvenile)	39	2	4.9 1.4	4.0 0.9	34.2 22.7	2.21 3.24	3.22	3.62
Parophrys vetulus, English sole (10 adults, 131 juveniles, 2 postlarvae, 2 unstaged)	145	13	3.8 1.5	3.6 1.3	19.7 32.4	0.08 0.19	3.68	3.67
Platichthys stellatus, starry flounder (28 adult, 14 juvs.)	42	36	2.9 2.0	2.9 1.8	24.7 64.9	2.54 4.61	3.00	2.54
Pleuronichthys coenosus, C-O sole (11 adult, 1 juvenile)	12	8	5.0 1.8	4.1 1.1	27.8 21.4	3.94 6.12	1.86	1.52
Psettichthys melanostictus, sand sole (25 adult, 106 juveniles)	131	6	4.6 1.4	4.1 1.2	24.4 49.5	0.36 0.77	2.73	3.43
Total	1,509							

spectrum (*see* II-H) was constructed. When the sample was divided among two or more seasons, prey composition by season was tabulated. Comparison of prey composition for samples of species collected by both beach seine and townet was also tabulated. Remaining species analyzed were either infrequently encountered predators or rare species for which little food habit information exists in the literature; thus, some idea of their trophic role in the nearshore food web was desirable. Data for all species can be found in a separate data set available through MESA or the Fisheries Research Institute (FRI).

III-H-1. Overall Prey Composition

Prey items consumed by nearshore demersal fishes were dominated by epibenthic crustaceans, especially harpacticoid copepods, mysids, cumaceans, tanaids, isopods, gammarid amphipods, and shrimp, which together formed over 50 percent of the occurrences of prey items in the stomachs. Neritic fishes fed on a less diverse spectrum of prey; pelagic organisms predominated, including calanoid copepods, euphausids, larvaceans, hyperiid and gammarid amphipods, and fishes (Appendix 9).

III-H-2. Species Specific Prey Spectra

Squalus acanthias, Spiny Dogfish

The few spiny dogfish captured in the nearshore region of the Strait of Juan de Fuca had frequently preyed upon gammarid amphipods, although crangonid shrimp were numerically more abundant in the stomach contents; the lithodid crab, *Haplogaster mertensi*, unidentified fish, and arenicolid polychaetes also contributed significantly to the total prey biomass.

Raja binoculata, Big Skate

One juvenile big skate captured by beach seine at Twin Rivers in August 1976 had fed primarily upon gammarid amphipods, mysids, and crangonid shrimp; amphipods and shrimp composed over 90 percent of the total biomass.

Raja abyssicola

An adult *R. abyssicola* beach seined at Beckett Point in January 1977 had consumed only shrimp, *Pandalopsis dispar* and *Heptacarpus* sp., with the former composing almost 80 percent of the contents biomass.

Raja stellulata, Starry Skate

Two starry skates, caught at Beckett Point in January 1977, had consumed a more diverse assortment than the *R. abyssicola*. The principal prey items were also shrimp, specifically *Pandalus danae*, *Pandalopsis ampla*, *Heptacarpus sitchensis*, and *Crangon abyssorum*, which composed 46 percent of the total number of prey and 60 percent of the contents biomass.

Clupea harengus pallasi, Pacific Herring

Juvenile Pacific herring, the dominant neritic fish in the nearshore environs of the Strait of Juan de Fuca, were characterized by a high incidence of empty stomachs and generally low stomach fullness and a high degree of digestion, suggesting a diurnal feeding period. The overall prey spectrum (Fig. 10) indicates that herring juveniles are almost exclusively planktivores, with calanoid copepods composing over 90 percent of the total number of prey and 64 percent of the total contents biomass. Mysids made up only 1.3 percent of the total number of prey organisms. However, they constituted 30 percent of the total biomass.

While the sample sizes for spring and winter are insufficient to make a reliable comparison, there was evidence of seasonal variations in prey composition (Table 5) with crab zoea making the largest contribution

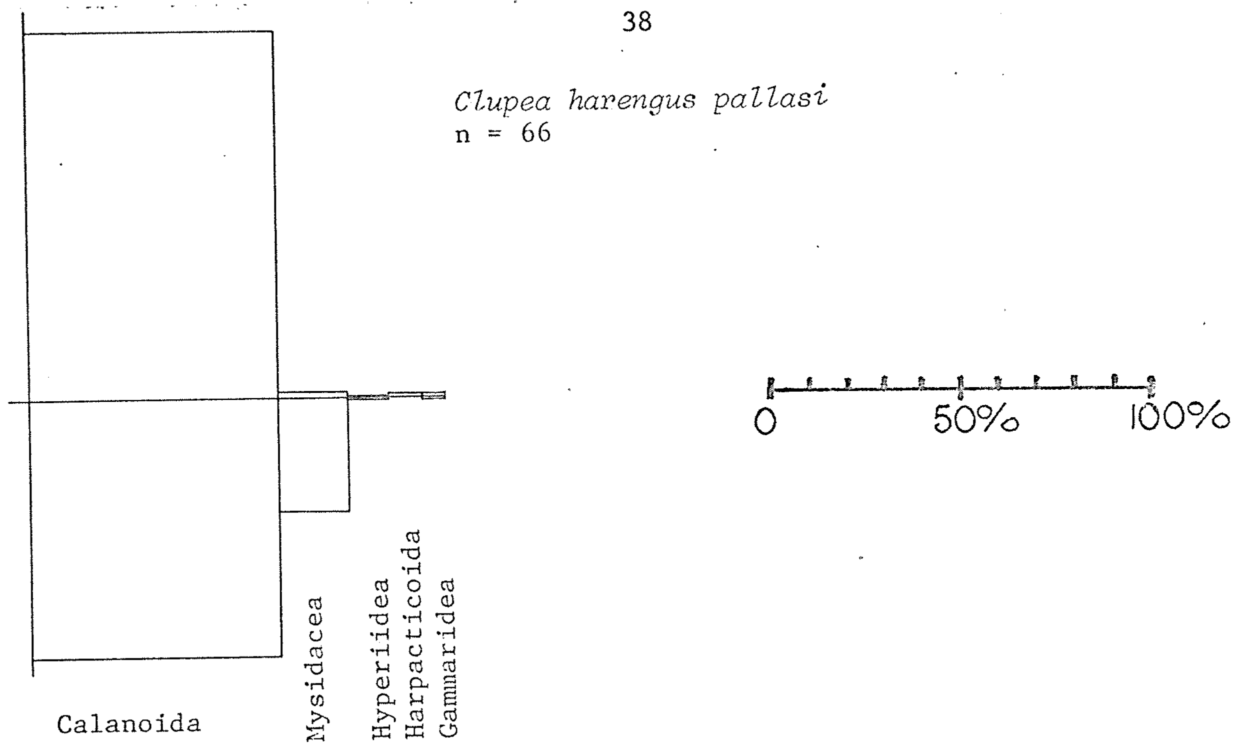


Fig. 10 . Composite I.R.I. prey spectrum for juvenile Pacific herring in Strait of Juan de Fuca, May 1976 – January 1977.

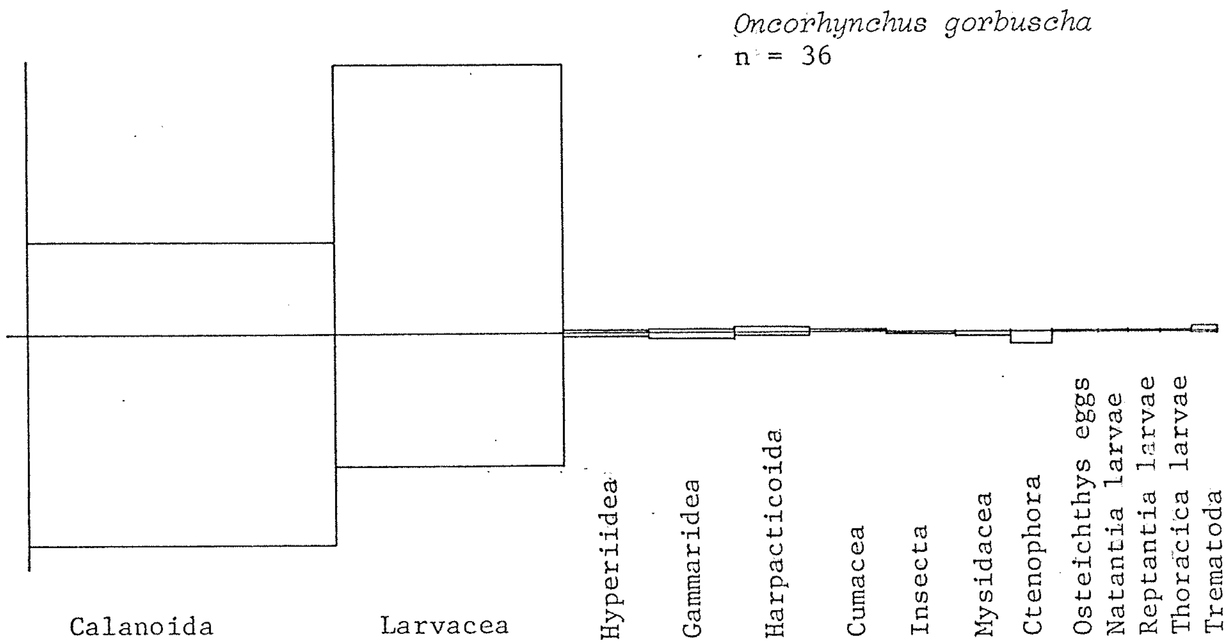


Fig. 11. Composite I.R.I. prey spectrum for juvenile pink salmon in Strait of Juan de Fuca, May 1976 - January 1977.

Table 5. Dominant prey items by seasons of juvenile Pacific herring caught by townet in Strait of Juan de Fuca, May 1976 - January 1977.

	Frequency of occurrence %	%Composition Abundance	%Composition Biomass
Spring (May) n = 8			
Crab zoea	67	79.41	77.49
Shrimp	33	2.94	7.46
Harpacticoid copepods	33	5.88	0.29
Gammarid amphipods	17	4.41	7.31
Calanoid copepods	17	2.94	4.39
Gastropods	17	2.94	2.92
Pelecypods	17	1.47	0.15
H' (abundance) = 1.24			
H' (biomass) = 1.23			
Summer (August) n = 56			
Calanoid copepods	78	98.62	96.99
Crustacea	11	1.23	1.30
Harpacticoid copepods	4	0.08	0.01
Mysids	4	0.03	1.55
Hyperiid amphipods	4	0.03	0.14
Crab larvae	4	0.03	0.01
H' (abundance) = 0.45			
H' (biomass) = 0.41			
Fall (October) n = 28			
Calanoid copepods	65	92.54	70.10
Hyperiid amphipods	35	1.25	1.45
Mysids	29	1.02	26.30
Gammarid amphipods	18	2.10	1.01
Harpacticoid copepods	12	1.99	0.56
Cumaceans	6	1.00	0.55
Tunicates	6	0.08	0.01
Barnacle larvae	6	0.03	0.01
H' (abundance) = 0.56			
H' (biomass) = 1.11			
Winter (December) n = 9			
Mysids	100	87.32	99.17
Gastropods	25	12.68	0.83
H' (abundance) = 0.55			
H' (biomass) = 0.07			

to a diverse diet in spring, calanoid copepods dominating the less diverse summer and fall diet, and mysids being the only important prey during winter.

Engraulis mordax, Northern Anchovy

Northern anchovies were infrequently encountered in the neritic waters along the Strait of Juan de Fuca. Calanoid copepods, the principle prey items, were found in 55 percent of the samples; they constituted 83 percent of the total prey, though only 6 percent of the total biomass. Harpacticoid copepods were found in 36 percent of the fish stomachs but only contributed 5 percent to the total number of prey. Mysids and phyllodocid polychaetes appeared in only 6 percent of the fish stomachs, but composed 62.5 percent and 18.4 percent, respectively, of the total biomass.

Oncorhynchus gorbuscha, Pink Salmon

Juvenile pink salmon were encountered in the neritic waters at the eastern sites during August and October, with the highest incidence occurring at Jamestown in August. A high percentage of empty stomachs, low mean fullness, and high digestion factors suggest cessation of feeding at dark.

The composite prey spectrum (Fig. 11) indicates a general pelagic feeding habit; calanoid copepods, larvaceans, hyperiid and gammarid amphipods, insects, ctenophores, cumaceans and harpacticoid copepods were the principal prey, with calanoids and larvaceans together consitituting 91.8 percent of the total number of prey and 88.1 percent of the total content biomass.

Table 6 presents a comparison between the summer and fall diets of neritic juvenile pink salmon. Bearing in mind the small sample size of the fall collections, the data imply that pelagic organisms, especially calanoid copepods, became more important between August and October.

Table 6. Dominant prey items by seasons of juvenile pink salmon caught by townet in Strait of Juan de Fuca, August and October, 1976.

	Frequency of occurrence %	% Composition Abundance	% Composition Biomass
Summer (August) n = 28			
Calanoid copepods	75	12.08	30.93
Larvaceans	71	81.71	61.25
Harpacticoid copepods	21	2.04	2.06
Cumaceans	18	0.71	0.52
Gammarid amphipods	18	0.35	0.98
Hyperiid amphipods	14	0.13	0.16
Osteichthys eggs	14	0.13	0.49
Insects	14	0.08	0.43
H' (abundance) = 1.02			
H' (biomass) = 1.49			
Fall (October) n = 7			
Calanoid copepods	100	83.61	83.68
Hyperiid amphipods	57	6.48	3.03
Mysids	57	2.07	1.82
Insects	43	0.78	0.61
Gammarid amphipods	29	2.98	2.75
Ctenophores	29	0.91	5.74
Shrimp	29	2.01	1.78
H' (abundance) = 1.07			
H' (biomass) = 1.05			

Larvaceans, which dominated in August, may be a seasonal, patchily distributed prey organism, explaining its disappearance from the diet.

Oncorhynchus keta, Chum Salmon

Juvenile chum salmon were caught nearshore by beach seine in May at the two westernmost sites; highest abundance was at Kydaka Beach. The lack of empty stomachs and high mean indices of stomach fullness and digestion suggest that these juvenile salmonids are diurnal feeders.

Epibenthic organisms were the major prey items. Harpacticoid copepods (94 percent), gammarid amphipods (88 percent), and cumaceans (35 percent) were the most frequently occurring items and combined, they formed 89.8 percent of the total number of prey and 75.4 percent of the total biomass. However, pelagic calanoid copepods were also present in 82 percent of the fish and 7.6 percent of the total number of prey and 15.2 percent of the total biomass.

Oncorhynchus kisutch, Coho Salmon

Four juvenile coho salmon captured in certain beach seine and townet collections had fed predominantly upon gammarid amphipods (80.6 percent total abundance, 90.0 percent total biomass) and cumaceans (14.3 percent total abundance, 5.3 percent total biomass).

Oncorhynchus tshawytscha, Chinook Salmon

Juvenile chinook salmon were encountered primarily at the western sites in August. Insects were the most frequently occurring prey (36 percent) but calanoid copepods comprised the most abundant prey (67.8 percent total abundance) and juvenile fish (38.8 percent total biomass), and syllid polychaetes (30.4 percent total biomass) composed most of the prey biomass. This suggests a generally pelagic feeding habit.

Salmo gairdneri, Rainbow (Steelhead) Trout

One adult anadromous rainbow trout captured during beach seining at Morse Creek in August had an empty stomach; another caught at Twin Rivers in January had consumed only mysids.

Hypomesus pretiosus, Surf Smelt

Like the juvenile Pacific herring, surf smelt captured by the townet at night had a high percentage of empty stomachs (66 percent) and low mean stomach fullness and digestion factors (1.9 for each). Those captured by beach seine (during daylight in August) exhibited a different trend (19 percent empty, 3.2 stomach fullness, and 3.1 digestion factor).

In both townet and beach seine samples, calanoid copepods dominated the low diversity prey spectrum (Fig. 12). Harpacticoid copepods, gammarid amphipods, and cumaceans also occurred frequently in the stomachs, but generally did not contribute significantly to the overall diet. Mysids, which occurred in 9 percent of the stomachs, constituted 23.6 percent of the total contents biomass.

There was an indication that beach seine collected surf smelt tended to prey more upon the epibenthic organisms of the shallow subtidal habitat; mysids made a significant contribution to the total prey biomass (Table 7).

Spirinchus thaleichthys, Longfin Smelt

The Twin Rivers and Pillar Point sites were notable for the higher catches of longfin smelt, especially during the summer. As with Pacific herring and surf smelt, fullness and digestion indices suggest that these fish feed primarily during the day.

Compared to the surf smelt and herring, longfin smelt had a relatively diverse prey spectrum. The most commonly encountered prey were,

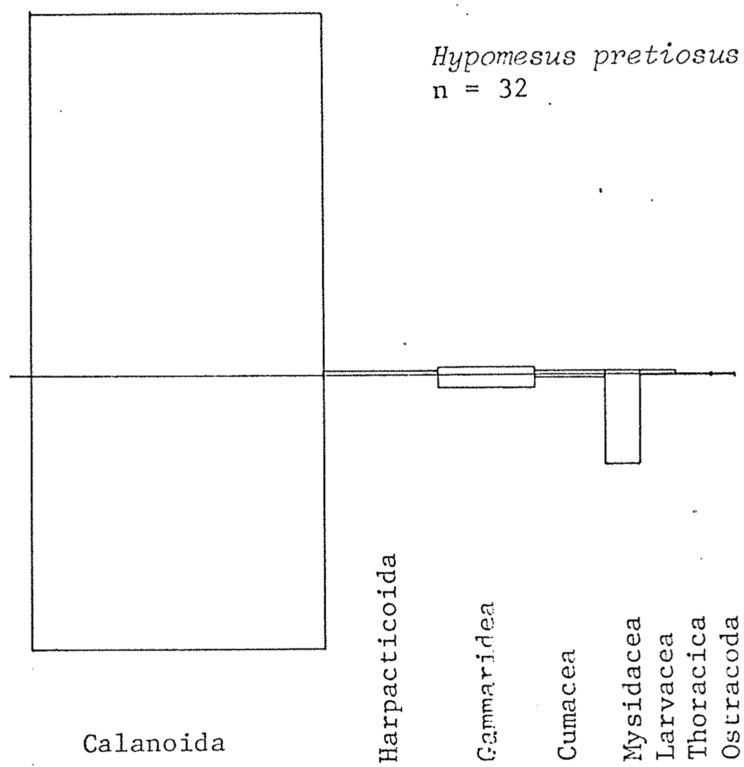


Fig. 12. Composite I.R.I. prey spectrum for surf smelt in Strait of Juan de Fuca, May 1976 - January 1977.

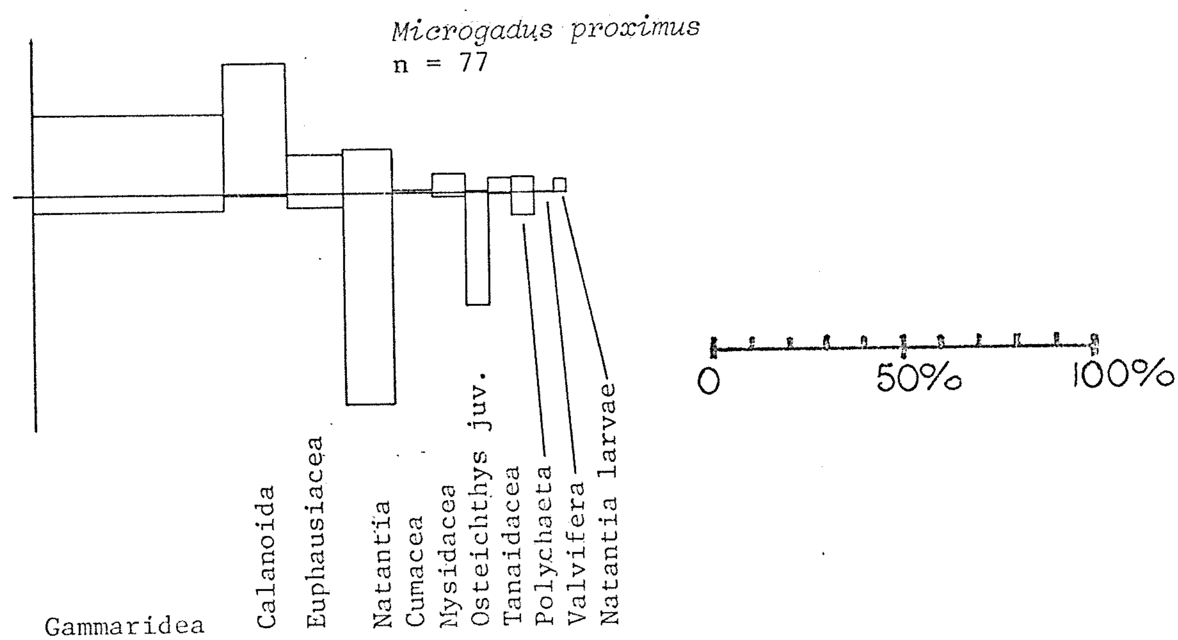


Fig. 13. Composite I.R.I. prey spectrum for Pacific tomcod in Strait of Juan de Fuca, May 1976 - January 1977.

Table 7. Dominant prey items of surf smelt captured by townet and beach seine in Strait of Juan de Fuca, May 1976-January 1977.

	Frequency of occurrence %	% Composition	
		Abundance	Biomass
Tow net, n = 15			
Calanoid copepods	73	92.57	90.40
Cumaceans	27	3.05	2.08
Gammarid amphipods	20	0.66	1.23
Barnacle larvae	20	0.41	0.09
Harpacticoid copepods	13	0.50	0.02
Mysids	7	0.41	3.01
H' (abundance) = 0.59			
H' (biomass) = 0.70			
Beach seine, n = 17			
Calanoid copepods	76	92.84	50.55
Harpacticoid copepods	41	1.19	0.19
Gammarid amphipods	29	2.99	4.37
Larvaceans	18	1.30	0.38
Mysids	12	1.49	43.77
Cumaceans	12	0.21	0.75
H' (abundance) = 0.52			
H' (biomass) = 1.33			

in order of frequency of occurrence, mysids, gammarid amphipods, cumaceans, and calanoid copepods--all but the latter being epipelagic organisms. Calanoids, gammarids, mysids, and shrimp zoea (in declining order) comprised the more abundant organisms while mysids, calanoids, and gammarids dominated the total biomass of the contents.

Porichthys notatus, Plainfin Midshipman

A single adult plainfin midshipman caught in August at Beckett Point had consumed one polychaete and one fish.

Gobiesox maeandricus, Northern Clingfish

Two postlarval northern clingfish caught during beach seine sampling at Morse Creek in October had nearly empty stomachs, with no identifiable prey.

Gadus macrocephalus, Pacific Cod

Two juvenile Pacific cod were caught during the January collections at Beckett Point. Shrimp composed most of the identifiable prey (76.9 percent total abundance, 45.1 percent total biomass) with one fish comprising 52.7 percent of total biomass.

Microgadus proximus, Pacific Tomcod

Juvenile and adult Pacific tomcod occurred in collections made from summer through winter collections, both by beach seine and townet; catches were almost exclusively confined to the sites east of Port Angeles with Beckett Point providing the more sizeable samples.

The overall prey spectrum of Pacific tomcod is extremely diverse, with benthic and epibenthic organisms providing the more important prey (Fig. 13). Gammarid amphipods were the prey most frequently encountered in stomachs but calanoid copepods, shrimp, crabs, and euphausids were the more important prey items, on the basis of numerical and biomass contributions.

Bearing in mind differences in collection periods, a comparison of the prey spectra of Pacific tomcod captured by the beach seine and the townet (Table 8) indicates possible differences in food habits of fish in neritic versus nearshore demersal habitats. Beach seine captured fish consumed a greater percentage of calanoid copepods with high biomass contributions by shrimp; townet caught fish, on the other hand, fed predominantly upon gammarid amphipods, euphausids, and calanoid copepods, while fish (including juvenile Pacific herring) and polychaetes dominated the total content biomass.

One significant seasonal difference is evident between prey composition for fall and winter (beach seine) caught Pacific tomcod (Table 9); polychaetes and tanaids occur only in the winter sample.

Theragra chalcogramma, Walleye Pollock

The occurrence of juvenile walleye pollock was similar to that of the Pacific tomcod; the eastern sites, especially Jamestown and Beckett Point, provided the more numerous samples. Walleye pollock also tended to be more abundant during the nighttime beach seine collections in October and January while it was common in the townet catches only in August and October.

The prey spectrum for this species was diverse as indicated by the 21 prey taxa recorded but it was numerically dominated by calanoid copepods (Fig. 14). Biomass composition was more diverse, however, with hippolytid and pandalid shrimp, gammarid amphipods, fish, and mysids also contributing to the total biomass.

Gasterosteus aculeatus, Threespine Stickleback

Adult threespine stickleback were caught at Beckett Point and Dungeness Spit in October and January. Harpacticoid copepods were the

Table 8. Dominant prey items of Pacific tomcod captured by beach seine and townet in Strait of Juan de Fuca, May 1976 - January 1977.

	Frequency of occurrence %	% Composition Abundance	% Composition Biomass
Beach seine, n = 40			
Gammarid amphipods	30	12.71	5.21
Polychaetes	13	4.04	1.91
Shrimp	10	9.10	73.72
Mysids	10	5.94	2.64
Tanaids	10	5.06	0.41
Calanoid copepods	7	54.77	0.28
Cumaceans	7	0.72	0.03
Fish	5	0.29	15.43
Clam siphons	5	2.02	0.15
H' (abundance) = 2.88			
H' (biomass) = 2.48			
Townet, n = 37			
Gammarid amphipods	70	29.35	2.93
Euphausids	27	19.05	4.95
Calanoid copepods	24	13.49	0.49
Shrimp	19	15.17	36.06
Isopods	14	1.81	0.25
Cumaceans	14	1.67	0.13
Tanaids	11	2.50	0.09
Fish	8	0.56	41.27
Mysids	8	2.78	0.72
Polychaetes	8	5.15	11.27
Caprellid amphipods	8	0.56	0.03
Shrimp larvae	5	5.84	0.08
Crab larvae	5	0.42	0.01
Harpacticoid copepods	5	0.42	0.01
H' (abundance) = 3.39			
H' (biomass) = 3.46			

Table 9. Dominant prey items by season of Pacific tomcod captured by beach seine in Strait of Juan de Fuca, October 1976 and January 1977.

	Frequency of occurrence %	% Composition Abundance	% Composition Biomass
Fall (October) n = 15			
Gammarid amphipods	47	24.80	3.82
Shrimp	27	42.15	75.69
Fish	13	1.65	17.69
H' (abundance) = 3.63			
H' (biomass) = 2.07			
Winter (January) n = 19			
Gammarid amphipods	32	24.35	15.10
Polychaetes	26	25.22	18.48
Tanaids	21	23.47	2.73
Shrimp	11	10.44	60.03
H' (abundance) = 3.24			
H' (biomass) = 2.66			

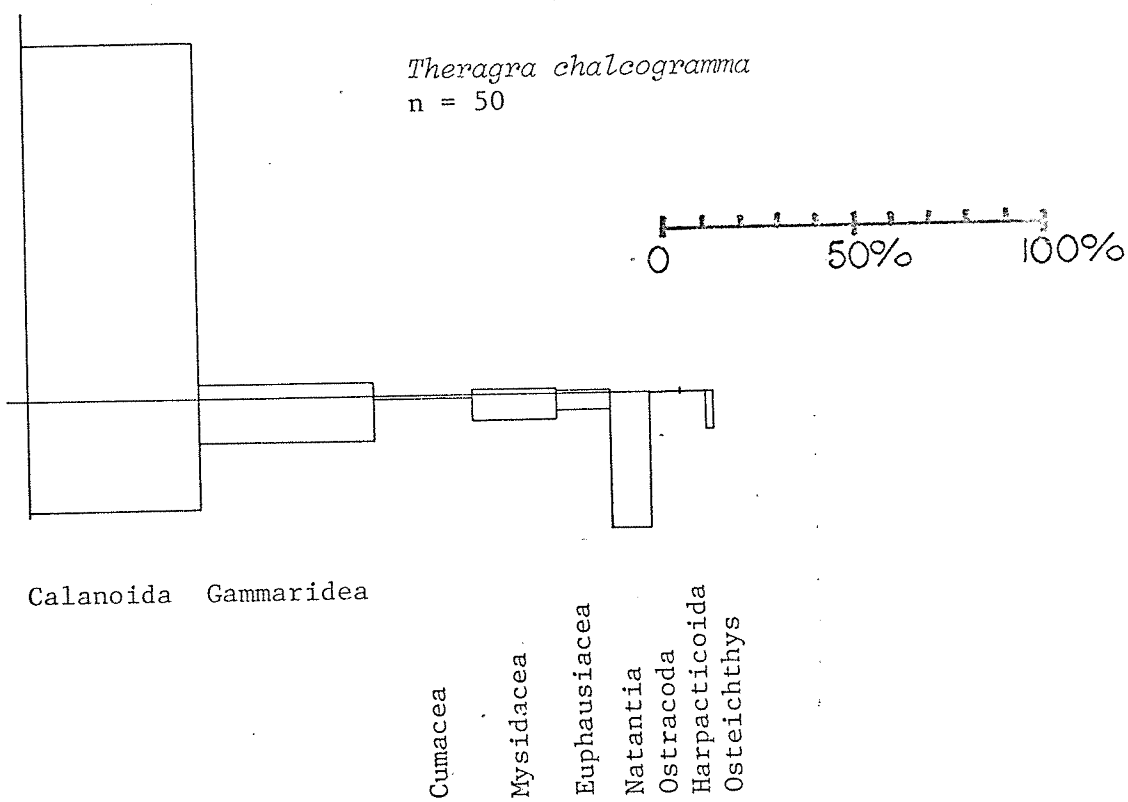


Fig. 14. Composite I.R.I. prey spectrum for juvenile walleye pollock in Strait of Juan de Fuca, May 1976 - January 1977.

most abundant prey in the stomachs, followed by calanoid copepods and gammarid amphipods; gammarids contributed 53 percent of the total biomass.

Aulorhynchus flavidus, Tube-snout

The most abundant catches of tube-snout occurred at Beckett Point in beach seine samples in January and in townet collections at Morse Creek in May and at Beckett Point in October.

Calanoid copepods, harpacticoid copepods, and shrimp larvae were the most important organisms (Fig. 15); shrimp larvae made the highest contribution to the total content biomass. Comparison between townet and beach seine samples showed townet caught tube-snouts to be feeding predominantly on pelagic calanoid copepods, shrimp larvae, and juvenile fishes, while beach seine caught tube-snouts appeared to feed more generally upon epibenthic organisms--harpacticoid copepods and mysids (Table 10).

Syngnathus griseolineatus, Bay Pipefish

Seven bay pipefish, caught at Beckett Point during January by the beach seine, had fed upon gammarid amphipods (81.6 percent total abundance, 45.0 percent total biomass), mysids (13.2 percent total abundance, 37.8 percent total biomass), and tanaids (5.3 percent total abundance; 17.2 percent total biomass).

Sebastes sp. (Postlarval) Rockfish

Two postlarval rockfish captured during August by the townet at Beckett Point had consumed one unidentifiable crustacean.

Hexagrammos stelleri, Whitespotted Greenling

The only significant numbers of whitespotted greenling encountered along the Strait of Juan de Fuca during our sampling were caught by

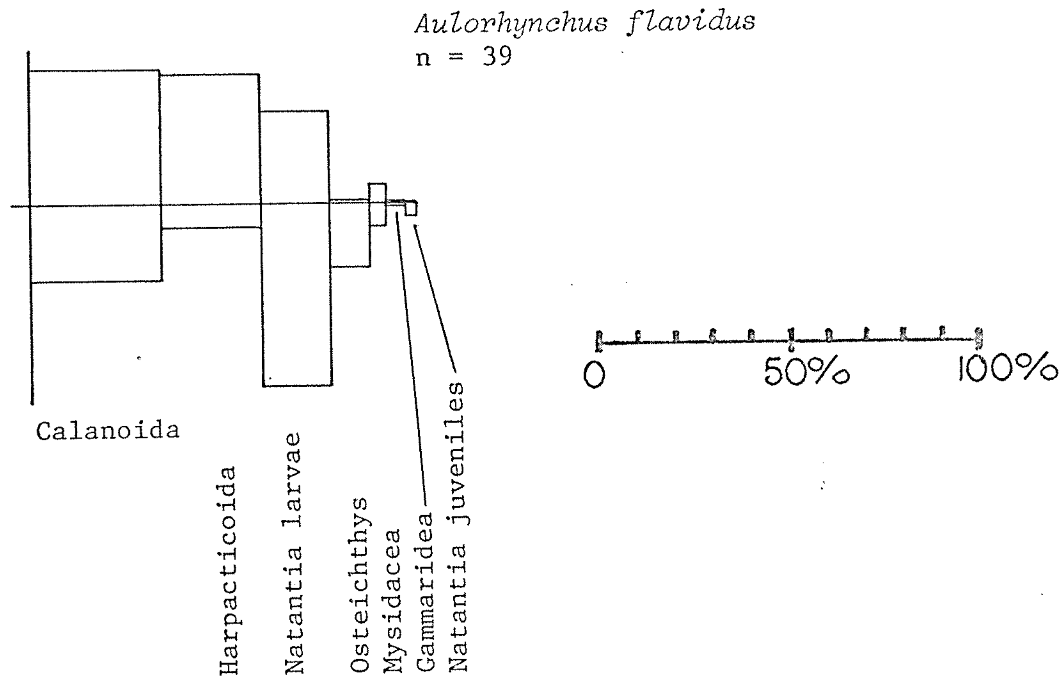


Fig. 15. Composite I.R.I. prey spectrum for tube-snout in Strait of Juan de Fuca, May 1976-January 1977.

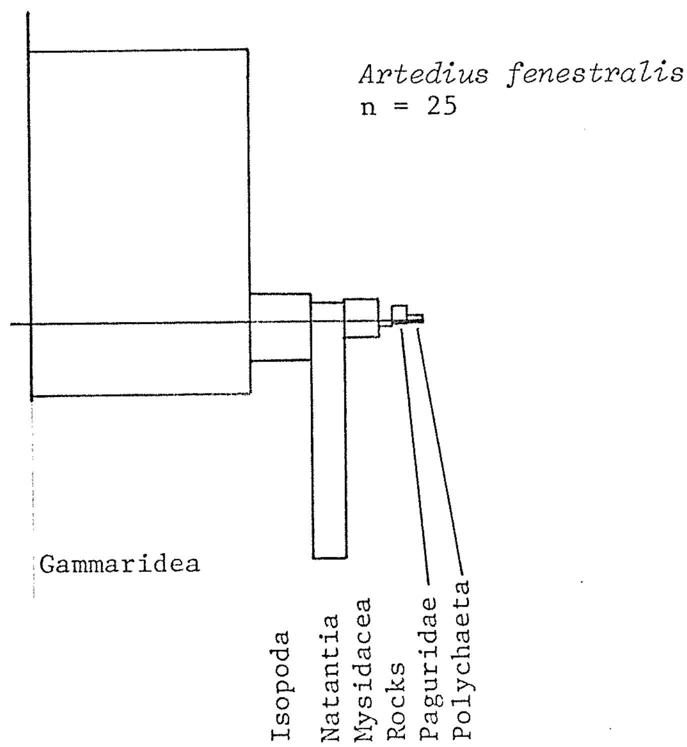


Fig. 16. Composite I.R.I. prey spectrum for padded sculpin in Strait of Juan de Fuca, May 1976 - January 1977.

Table 10. Dominant prey items of tube-snouts captured by townet and beach seine in Strait of Juan de Fuca, May 1976-January 1977.

	Frequency of occurrence %	% Composition	
		Abundance	Biomass
Tow net, n = 11			
Calanoid copepods	100	52.92	21.98
Shrimp larvae	64	42.98	53.29
Fish juveniles	36	1.30	19.20
Shrimp juveniles	9	1.08	3.72
Mysids	9	0.22	1.57
H' (abundance) = 1.27			
H' (biomass) = 1.71			
Beach seine, n = 28			
Harpacticoid copepods	25	73.53	45.84
Calanoid copepods	7	13.90	4.17
Mysids	7	11.23	41.67
Gammarid amphipods	7	1.07	5.56
Crab zoea	4	0.27	2.78
H' (abundance) = 2.18			
H' (biomass) = 2.19			

beach seine at Beckett Point in winter. Their stomachs averaged 75 percent full, with over 50 percent of the contents identifiable.

Typical of hexagrammids, these specimens had fed upon a wide diversity of benthic and epibenthic fauna; no prey taxon was represented by more than 50 percent of the total sample. Gammarid amphipods occurred most frequently (47 percent of stomachs examined) and composed the highest proportion of the total number of prey (38.4 percent), but only a small proportion (2.1 percent) of the ingested biomass. Polychaetes, tanaids (second most abundant prey), gastropods, leptostracans, pagurid crabs and true crabs composed most of the other prey items. Of the total biomass, 48.3 percent was composed of five juvenile brachyuran crabs, *Pugettia gracilis*, all of which occurred in one stomach.

Ophiodon elongatus, Lingcod

One juvenile lingcod, caught by beach seine at Beckett Point in January, had consumed one unidentifiable fish.

Artedius fenestralis, Padded Sculpin

This small sculpin was frequently present in beach seine collections all along the Strait of Juan de Fuca; the winter sample at Twin Rivers produced the largest sample.

The overall prey spectrum of *A. fenestralis* (Fig. 16) indicates a feeding habit generally based upon epibenthic crustaceans, primarily gammarid amphipods, shrimp, mysids, and isopods.

Ascelichthys rhodorus, Rosylip Sculpin

Rosylip sculpins were sampled generally throughout the year, principally by beach seine; the Twin Rivers collection in August was the most productive.

The diet of *A. rhodorus* was predominantly benthic and epibenthic crustaceans. Gammarid amphipods were the most common organism in the sample (47 percent), comprising 54.8 percent of the total number of prey items and 25.1 percent of the total prey biomass. Mysids were almost as common (41 percent) but did not constitute as great a proportion of the diet (14.2 percent total abundance, 11.7 percent total biomass). Isopods, including *Gnorimosphaeroma oregonensis*, accounted for 28.4 percent of the total number of prey and 30.4 percent of the prey biomass. Other prey items were crangonid shrimp, juvenile sculpins, and organic debris.

Blepsias cirrhosus, Silverspotted Sculpin

One of the more common cottids of the nearshore demersal assemblage at Twin Rivers and Morse Creek was the silverspotted sculpin. The overall prey spectrum (Fig. 17) illustrates the general dominance of epibenthic crustaceans--gammarid amphipods and mysids--which comprised the majority of the prey numbers and biomass.

Seasonal differences in diet composition between summer and winter were slight (Table 11). Gammarid amphipods were more important in the winter while mysids were somewhat more important during the summer.

Clinocottus acuticeps, Sharpnose Sculpin

Two sharpnose sculpins were caught by beach seine in the spring and summer collections. Epibenthic crustaceans (mysids, gammarid amphipods, and harpacticoid copepods) and pelagic organisms (fish larvae, calanoid copepods, and gastropod veliger larvae) were well-represented in the diet.

Enophrys bison, Buffalo Sculpin

Buffalo sculpin were common, but not abundant, in Twin Rivers and Beckett Point beach seine catches throughout the year. Twenty-five percent of the stomachs were empty, though the mean stomach fullness was

Table 11. Dominant prey items by season of silverspotted sculpin caught by beach seine in Strait of Juan de Fuca, August 1976 and January 1977.

	Frequency of occurrence %	% Composition Abundance	% Composition Biomass
Summer (August) n = 11			
Mysids	73	73.88	56.22
Gammarid amphipods	73	10.83	8.51
Isopods	18	1.91	2.18
Shrimps	9	13.37	33.08
H' (abundance) = 1.61			
H' (biomass) = 2.15			
Winter (January) n = 21			
Mysids	48	56.69	42.26
Gammarid amphipods	38	40.88	54.36
Isopods	10	0.81	1.05
Algae	10	0.81	2.33

approximately 50 percent; this is usually indicative of a macrophagous predator. Gammarid amphipods were the most frequently encountered prey item (42 percent) but contributed only 8.7 percent of the total number of items and 1.0 percent of the total biomass.

Oddly enough, the second most common prey item (25 percent) in the total sample was algae (typically ulvoid) which constituted 28.3 percent of the total number of items and 62.8 percent of the total biomass. While it is not unusual for benthic-feeding fishes to consume algae incidentally with epibenthic organisms, the bite-sized character and the high incidence of the algae suggest that *E. bison* may be feeding upon algae. Other representative prey included polychaetes (12.5 percent total abundance, 1.1 percent total biomass), fish eggs (27.2 percent total abundance, 0.2 percent total biomass), fish (juvenile *Sebastes* included), and both astacuran and anomuran shrimp.

Leptocottus armatus, Staghorn Sculpin

The ubiquitous nearshore cottid, *Leptocottus armatus*, was prevalent in the nearshore demersal fish assemblages along the Strait of Juan de Fuca. Beckett Point, Twin Rivers, and Jamestown sites produced more staghorn sculpin than the other sites; winter collections also tended to capture more of this species.

The overall prey spectrum for *Leptocottus armatus* included a variety of benthic and epibenthic organisms (Fig. 18). Gammarid amphipods were the most common prey, although they occurred in only 11 percent of the stomachs sampled. Polychaetes, nematodes (probably parasitic), shrimp (including *Pandalus danae* and other Pandalidae, Crangonidae, Hippolytidae and Callianassidae--*Upogebia pugettensis*), fishes (including *Ammodytes hexapterus*, *Cymatogaster aggregata*, and pleuronectids), crabs (including *Cancer magister*, *Hemigrapsus oregonensis*, and *Telmessus cheiragonus*), and mysids composed the other principal prey taxa.

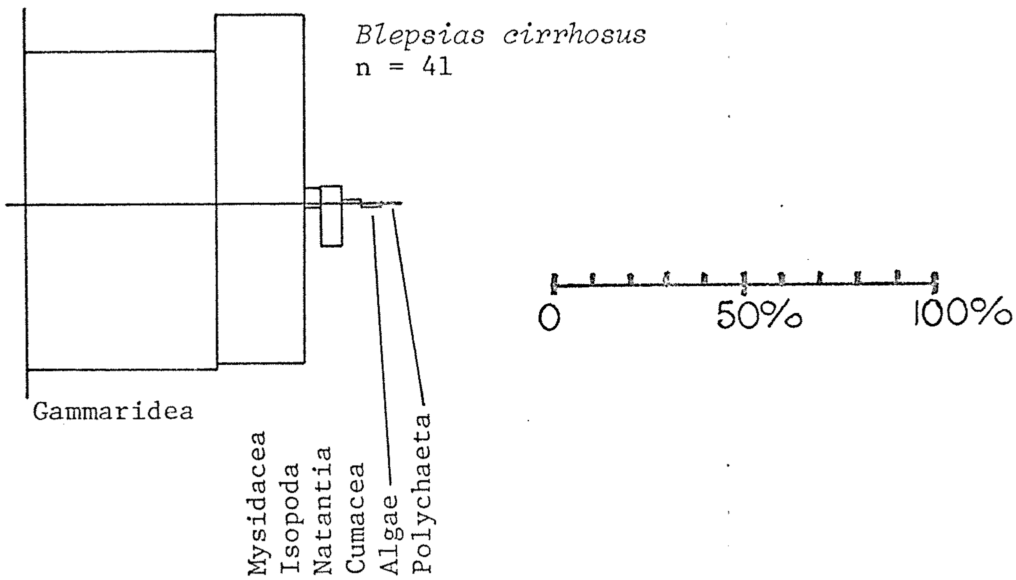


Fig. 17. Composite I.R.I. prey spectra of silverspotted sculpin in Strait of Juan de Fuca, May 1976 - January 1977.

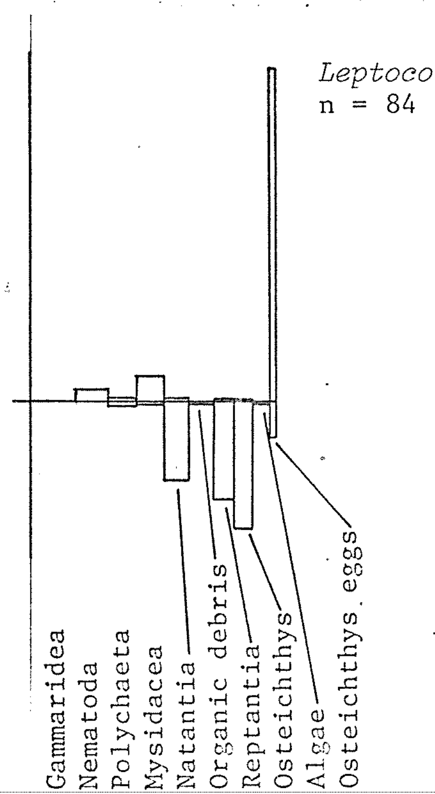


Fig. 18. Composite I.R.I. prey spectra of Pacific staghorn sculpin in Strait of Juan de Fuca, May 1976 - January 1977.

Seasonal differences in food habits are apparent (Table 12). While summer and fall stomach contents were numerically dominated by fish eggs, prey organisms from spring samples were predominantly nematodes (probably parasitic) and harpacticoid copepods and in winter were mysids. Prey biomass consisted primarily of clam siphons, shrimp and crabs in the spring; fish in the summer; crabs, fish eggs, and shrimp in the fall; and shrimp, fish, and crabs in the winter.

Myoxocephalus polyacanthocephalus, Great Sculpin

Juvenile great sculpin were encountered most frequently at Beckett Point in all seasons, but especially in summer.

Hippolytid shrimp completely dominated the prey composition, occurring in 23 percent of the specimens. If the eggs of these epibenthic shrimp are also included in this prey taxon, it accounted for 93.7 percent of the total number of prey and 37.8 percent of the prey biomass. Other shrimp (Crangonidae) contributed 1.9 percent of the total prey and 12.9 percent of the total prey biomass. Fish (including stichaeids) accounted for only 1.4 percent of the total prey, but 35.6 percent of the total prey biomass.

Scorpaenichthys marmoratus, Cabezon

Two cabezon captured by beach seine at Beckett Point in May had consumed brachyuran crabs--*Cancer gracilis*, *C. productus*, and *Telmessus cheiragonus*--which comprised 73.3 percent of the total prey and 98.4 percent of the total content biomass.

Chitonotus pugettensis, Roughback Sculpin

Roughback sculpin were most numerous in Beckett Point beach seine collections in January.

Shrimp, primarily hippolytid (*Heptacarpus* sp.) but including crangonid (*Crangon* sp., *Sclerocrangon alata*) and pandalid species, were the most

Table 12. Dominant prey items by season of Pacific staghorn sculpin caught by beach seine in the Strait of Juan de Fuca, May 1976–January 1977.

	% Frequency of occurrence	% Composition Abundance	% Composition Biomass
Spring (May) n = 9			
Harpacticoid copepods	33	4.91	0.00
Algae	33	0.45	1.18
Polychaetes	33	2.23	0.07
Crabs	22	3.58	20.41
Shrimp	22	2.23	26.00
Gammarid amphipods	22	3.57	0.08
Clam siphons	11	0.89	49.67
Nematodes	11	75.45	0.00
H' (abundance) = 1.67			
H' (biomass) = 1.96			
Summer (August) n = 19			
Mysids	16	1.01	0.65
Algae	16	0.13	2.59
Fish	11	0.20	63.88
Polychaetes	11	0.49	1.46
Gammarid amphipods	11	0.06	0.03
Crabs	11	0.12	14.32
Clam juveniles	11	0.04	0.02
Tanaids	11	0.08	0.01
Organic debris	11	0.15	1.30
Fish eggs	5	97.47	8.47
Shrimp	5	0.08	3.81
H' (abundance) = 0.27			
H' (biomass) = 3.32			
Fall (October) n = 20			
Gammarid amphipods	20	0.33	0.17
Shrimp	15	1.61	22.72
Organic debris	15	0.70	1.21
Crabs	10	0.37	37.97
Mysids	10	0.08	0.64
Isopods	10	0.53	1.50
Fish	10	0.19	13.15
Fish eggs	5	95.01	22.79
H' (abundance) = 0.50			
H' (biomass) = 3.71			

Table 12. cont'd

	% Frequency of occurrence	% Composition	
		Abundance	Biomass
Winter (January) n = 36			
Mysids	14	74.53	3.49
Shrimp	14	3.96	31.67
Nematodes	14	9.34	0.51
Fish	6	2.53	31.08
Crabs	6	0.96	23.77
Tanaids	6	3.64	0.03
Polychaetes	6	0.95	2.30
Gammarid amphipods	6	1.90	0.07
Organic debris	6	0.79	0.77
H' (abundance) = 2.64			
H' (biomass)= 3.71			

frequently occurring (14 percent of sample) and most numerous (39.6 percent) prey organisms; they comprised 84.0 percent of the total biomass (Fig. 19). Gammarid amphipods were found in 10 percent of the stomachs and comprised 11.2 percent of the total prey numbers and 1.5 percent of the total prey biomass. Other prominent prey items included harpacticoid copepods, mysids, polychaetes, and algae.

Occella verrucosa, Warty Poacher

Two specimens of *O. verrucosa* were captured at Dungeness Spit during October beach seine collections. One stomach contained six mysids (85.7 percent of the total prey abundance, 98.7 percent of the total prey biomass); the other contained one amphipod.

Pallasina barbata, Tubenose Poacher

These small poachers were caught infrequently at Twin Rivers, Morse Creek, and Dungeness Spit during August and October beach seining.

Essentially all (81 of 84) of the prey in the combined sample were mysids.

Agonus acipenserinus, Sturgeon Poacher

Sturgeon poachers were commonly encountered at Beckett Point; December beach seining provided a large sample.

The prey spectrum of *A. acipenserinus* (Fig. 20) is relatively diverse. Numerically, the principal prey items were cumaceans (33.5 percent), gammarid amphipods (20.6 percent), harpacticoid copepods (13.0 percent), and tanaids (11.2 percent). In order of their contribution to the total prey biomass, shrimp (44.8 percent), gammarid amphipods (20.1 percent), and polychaetes (9.8 percent) were the more significant prey taxa.

Chitonotus pugettensis
n = 29

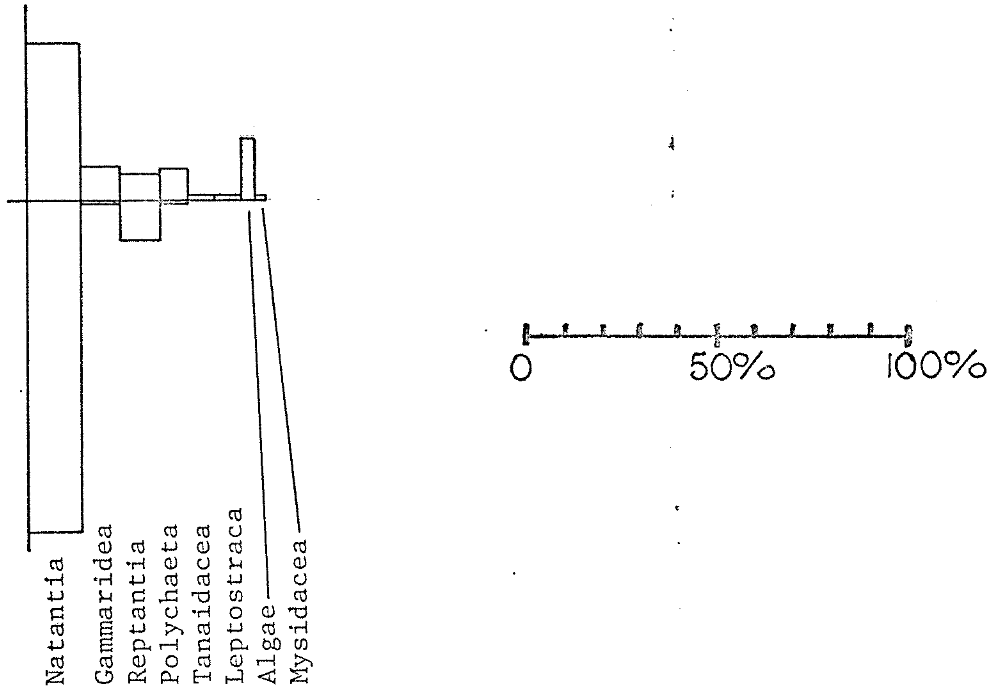


Fig. 19. Composite prey spectrum of roughback sculpin in the Strait of Juan de Fuca, May 1976 - January 1977.

Agonus acipenserinus
n = 28

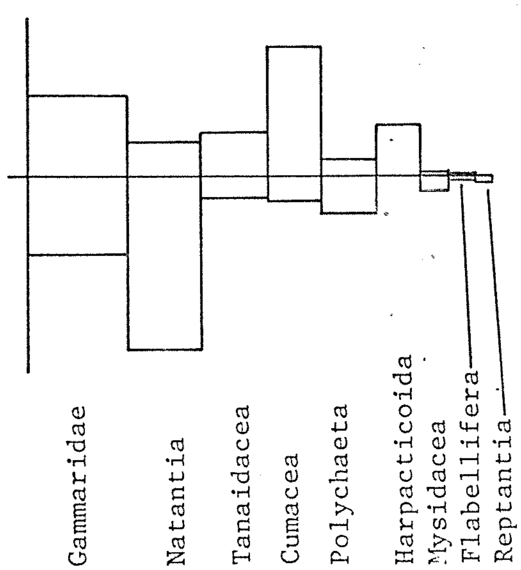


Fig. 20. Composite prey spectrum of sturgeon poacher in the Strait of Juan de Fuca, May 1976 - January 1977.

Liparis callyodon, Spotted Snailfish

One spotted snailfish from a Morse Creek townet sample in August had 12 caprellid amphipods among a large amount of organic detritus.

Liparis cyclopus, Ribbon Snailfish

Liparis cyclopus occurred infrequently in beach seine catches at Twin Rivers and Morse Creek.

One-third of the combined stomach sample contained gammarid amphipods, accounting for 86.7 percent of the total prey numbers and 87.9 percent of the total prey biomass. The remaining prey items were the isopod, *Gnorimosphaeroma oregonensis*, crangonid shrimp, and rocks.

Liparis florae, Tidepool Snailfish

A single tidepool snailfish captured at Morse Creek in a January beach seine collection contained 15 flabelliferan isopods and seven gammarid amphipods.

Liparis mucosus, Slimy Snailfish

This snailfish was most common in the spring beach seine collections at Twin Rivers and Kydaka Beach.

Eighty-five percent of the stomachs contained gammarid amphipods (69.2 percent total abundance, 80.5 percent total biomass); other epibenthic organisms--cumaceans, valviferan and flabelliferan isopods, mysids, and caprellid amphipods--composed the remaining prey items.

Liparis pulchellus, Showy Snailfish

Like *Liparis mucosus*, *L. pulchellus* were collected at two western sites along the Strait of Juan de Fuca. Five specimens from the October beach seine collections had fed mostly upon gammarid amphipods (90 percent of total prey abundance, 71.7 percent of total biomass). Mysids and cumaceans were less important prey items.

Cymatogaster aggregata, Shiner Perch

Shiner perch were often captured in abundance during beach seine collections at Beckett Point and Dungeness Spit and during townet sampling at the three sites east of Port Angeles. A high percentage of these specimens had empty stomachs and the mean stomach fullness and digestion factors were quite low (Table 13). This is typical for embiotocids and appears to be a function of a high rate of digestion. It does, however, reduce the effective sample size and make seasonal and habitat comparisons difficult.

Overall, gammarid amphipods were the dominant prey consumed, occurring in 35 percent of the stomachs and accounting for 49.5 percent of the total prey abundance and 69.7 percent of the total prey biomass. Although harpacticoid copepods were the next most common prey (20 percent), they accounted for only 9.5 percent of the total prey abundance and 0.4 percent of the total prey biomass. Calanoid copepods contributed 27.8 percent of the total number of prey and 2.2 percent of the prey biomass. Epibenthic organisms provided the remainder of the prey; in decreasing order of importance, these included mysids, tanaids, crangonid shrimp, polychaetes, isopods, and cyclopoid copepods.

Shiner perch caught in neritic habitats by the townet tended to consume pelagic prey organisms (calanoid copepods); those captured in nearshore demersal habitats consumed a wider diversity of epibenthic organisms (gammarid amphipods, mysids, harpacticoid copepods, tanaids and others) (Table 13).

Embiotoca lateralis, Striped Surfperch

Striped surfperch occurred in beach seine catches at all sites during all seasons, though not abundantly in August. Like the shiner

Table 13. Dominant prey items of shiner perch caught by beach seine and townet in the Strait of Juan de Fuca, May 1976 - January 1977.

	% Frequency of occurrence	% Composition	
		Abundance	Biomass
Tow net, n = 6			
Calanoid copepods	17	81.71	21.53
Harpacticoid copepods	17	17.51	1.96
Polychaeta	17	0.39	76.32
Gammarid amphipods	17	0.39	0.20
H' (abundance) = 0.74			
H' (biomass) = 0.90			
Beach seine, n = 14			
Gammarid amphipods	43	74.65	77.32
Mysids	21	6.59	8.42
Harpacticoid copepods	21	5.39	0.26
Tanaids	21	5.59	1.55
Nematodes	14	2.00	0.45
Isopods	7	1.40	0.65
Shrimp	7	0.20	8.21
Cyclopoid copepods	7	2.00	0.02
H' (abundance) = 2.02			
H' (biomass) = 1.57			

perch, the sample of *Embiotoca lateralis* contained a high percentage of empty stomachs.

Gammarid amphipods were the most commonly occurring prey (40 percent), accounting for 94.2 percent of all prey and 62.3 percent of the total prey biomass. Valviferan (*Idotea ochotensis*) and flabelliferan isopods composed only 1.9 percent of the prey but contributed 25.7 percent of the prey biomass. Other incidental prey included gastropods, polychaetes, and shrimp. All prey were exclusively benthic or epibenthic organisms.

Rhacochilus vacca, Pile Perch

The August and October townet collections at Beckett Point provided a sizable sample of pile perch. Unfortunately, 84 percent of the stomachs were empty; perhaps this is a result of the nocturnal collection of a diurnally feeding fish. The stomachs (three) with prey organisms contained gammarid amphipods (42.2 percent total abundance, 9.1 percent total biomass), valviferan isopods (22.2 percent total abundance, 60.8 percent total biomass), tanaids (22.2 percent total abundance, 0.1 percent total biomass), pagurid crabs (11.1 percent total abundance, 28.4 percent total biomass), and a shrimp. The prey of the remaining fish were epibenthic organisms.

Amphistichus rhodorus, Redtail Surfperch

Redtail surfperch commonly occurred in the beach seine catches at the western sites along the Strait of Juan de Fuca; they were especially abundant at Twin Rivers in August, October, and January. Unlike the other surfperches, the *Amphistichus rhodorus* sample had no empty stomachs; stomachs tended to be almost half full and less than half digested.

The overall prey spectrum (Fig. 21) illustrates a diverse feeding habit emphasizing epibenthic organisms. Gammarid amphipods and mysids predominated numerically while the total prey biomass was distributed

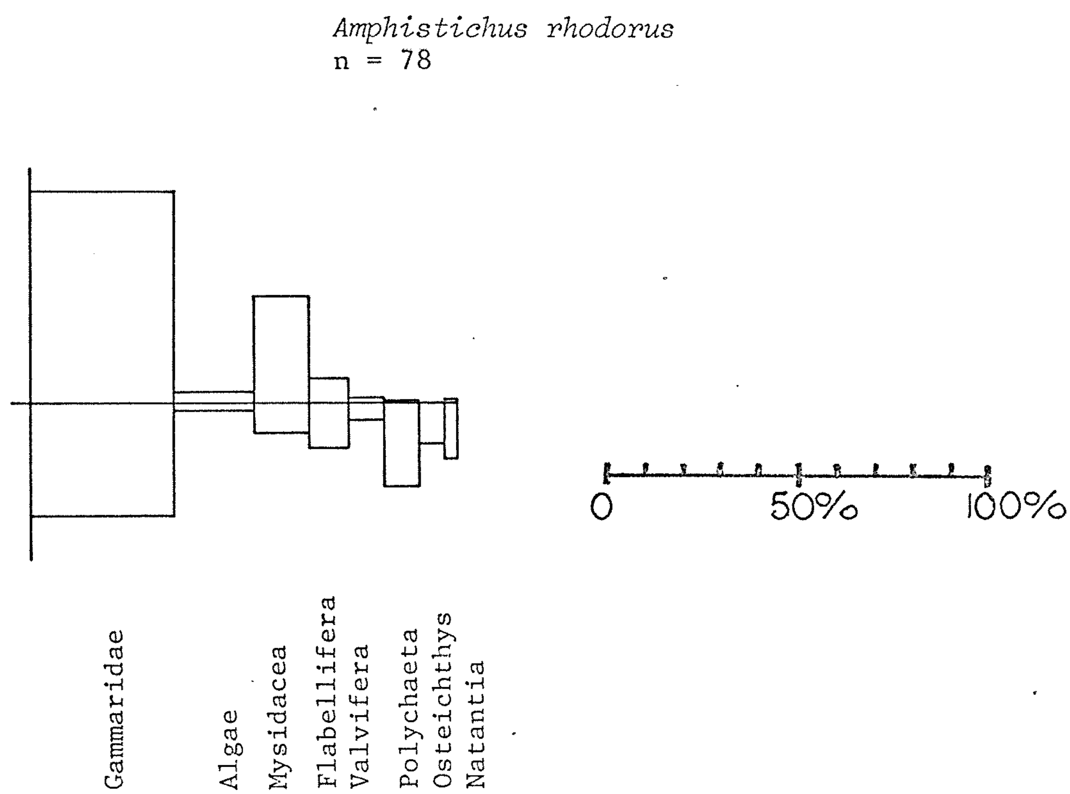


Fig. 21. Composite I.R.I. prey spectrum for redtail surfperch in Strait of Juan de Fuca, May 1976 - January 1977.

among gammarids, polychaetes (Glyceridae), shrimp (Crangonidae), flabelliferan isopods (*Gnorimosphaeroma oregonensis*), fish (Cottidae), and mysids (*Neomysis* sp.). The valviferan isopods were *Pentidotea resecata* and *P. wosnesenski*.

Seasonal variations in food habits are not extreme (Table 14). Gammarid amphipods were important prey in the seasons when redtail surfperch were caught; mysids were significant prey in summer and winter. The contribution by isopods, especially the flabelliferan *Gnorimosphaeroma oregonensis*, was much higher in the fall than in the two other seasons.

Trichodon trichodon, Pacific Sandfish

Three Pacific sandfish captured by both beach seine and townet had eaten mysids (*Neomysis* sp.) predominantly (92.5 percent total abundance; 86.3 percent total biomass).

Lumpenus sagitta, Snake Prickleback

A Beckett Point beach seine collection in August included three snake pricklebacks. All had fed on a diverse assemblage of epibenthic organisms, principally polychaetes (30.1 percent total abundance, 64.3 percent total biomass), gammarid amphipods (13.1 percent total abundance, 16.6 percent total biomass), and tanaids (20.4 percent total abundance, 16.6 percent total abundance). Nematodes, probably parasitic, accounted for 32.8 percent of the total items in the stomachs.

Apodichthys flavidus, Penpoint Gunnel

August beach seine collections at Jamestown, Morse Creek, and Twin Rivers provided a sample of seven adult and seven juvenile penpoint gunnels. Valviferan isopods (41.9 percent total abundance, 38.6 percent total biomass), mysids (30.0 percent total abundance, 34.5 percent total biomass), and gammarid amphipods (16.5 percent total abundance, 8.8 percent total biomass) constituted the principal prey organisms.

Table 14. Dominant prey items by season of redtail surfperch captured by beach seine in the Strait of Juan de Fuca, August 1976 - January 1977.

	% Frequency of occurrence	% Composition Abundance	% Composition Biomass
Summer (August), n = 10			
Gammarid amphipods	80	71.27	81.15
Mysids	60	24.03	14.33
Algae	60	2.75	2.84
Flabelliferan isopods	20	0.34	0.21
Hyperiid amphipods	10	1.49	0.71
H' (abundance) = 1.22			
H' (biomass) = 0.97			
Fall (October), n = 22			
Algae	45	7.96	3.34
Gammarid amphipods	41	24.42	9.24
Flabelliferan isopods	36	28.68	28.30
Valviferan isopods	32	4.78	5.88
Fish	14	1.24	30.07
Polychaetes	9	1.06	0.99
Shrimp	5	3.72	19.84
Rocks	5	22.12	0.07
Mysids	5	5.66	1.28
H' (abundance) = 3.23			
H' (biomass) = 3.00			
Winter (January), n = 46			
Gammarid amphipods	24	42.73	19.87
Mysids	24	45.23	7.61
Polychaetes	11	1.60	47.46
Flabelliferan isopods	9	6.32	3.39
Valviferan isopods	9	3.11	5.38
Shrimp	4	0.20	15.30
H' (abundance) = 3.35			
H' (biomass) = 3.40			

Pholis laeta, Crescent Gunnel

Crescent gunnels were commonly encountered at Morse Creek and Twin Rivers and appeared in both beach seine and townet collections. The most common (80 percent) prey in *Pholis laeta* stomachs was gammarid amphipods, accounting for 75.5 percent of the total number of prey items and 59.4 percent of the total prey biomass. Isopods, including *Idotea fewkesi* and *Gnorimosphaeroma oregonensis*, contributed 13.6 percent of the total prey and 40.2 percent of the total prey biomass. The remaining prey items included harpacticoid copepods, cumaceans, algae, and other organic debris.

Pholis ornata, Saddleback Gunnel

Five specimens of *P. ornata* from beach seine collections at Beckett Point and Twin Rivers exhibited food habits somewhat similar to *P. laeta*. Gammarid amphipods were the most frequently utilized prey (80 percent) accounting for 45.5 percent of all prey items and 5.6 percent of the total biomass. *Gnorimosphaeroma oregonensis* were present in 40 percent of the sample but contributed only 3.4 percent of all prey and less than 1 percent of the total biomass. Gastropods and harpacticoid copepods each totaled 10.2 percent, and tunicates 17.1 percent of the total number of prey; none of these, however, contributed more than 1 percent to the total content biomass. Two fishes, juvenile *Parophrys vetulus* and *Ammodytes hexapterus*, made up only 3.4 percent of all prey, but together composed 88.4 percent of the total content biomass.

Ammodytes hexapterus, Pacific Sand Lance

August and October beach seine samples at Dungeness Spit and Morse Creek included 19 Pacific sand lance, seven of which had empty stomachs. Calanoid copepods were the only important prey, composing 99.9 percent of the total prey and 34.3 percent of the total prey contents. The other organisms included a juvenile Pacific sand lance and one gammarid amphipod.

Citharichthys stigmaeus, Speckled Sanddab

Four speckled sanddabs were caught in the May beach seine collection at Beckett Point. Three contained polychaetes, contributing 31 percent of the total prey and 51.3 percent of the total biomass. Gammarid amphipods occurring in two fish made up another 47.0 percent of the prey and 10.9 percent of the prey biomass. Other less commonly utilized prey included bivalves and their siphons (9.1 percent total abundance, 7.9 percent total biomass), calanoid copepods, one shrimp (28.2 percent total biomass), an anomuran crab, one isopod, and algae.

Citharichthys sordidus, Pacific Sanddab

Winter beach seine collections at Dungeness Spit and Beckett Point produced Pacific sanddabs. Gammarid amphipods were common prey to three, contributing 68.4 percent of the prey and 3.8 percent of the prey biomass. Mysids (*Neomysis* sp.), shrimp (61.2 percent total biomass), and polychaetes were the other prey items.

Eopsetta jordani, Petrale Sole

A petrale sole caught in a January beach seine collection at Dungeness Spit had four gammarid amphipods in its stomach.

Lepidopsetta bilineata, Rock Sole

The dominant prey of rock sole was gammarid amphipods; they occurred in 66 percent of the samples and comprised 60 percent of all prey and 18 percent of prey biomass (Fig. 22). Tanaids occurred in 48 percent of the samples with only small contributions to abundance and biomass. Pelecypods, including siphons and whole specimens of *Yoldia scissurata* and *Clinocardium nuttallii*, occurred in 32 percent of the samples and comprised 5 percent of all prey species and 39 percent of prey biomass. Crabs were represented by *Cancer magister*, *Telemessus cheiragonus*, *Pinnixa* sp., pagurid, and pinnotherid species. Fishes consumed included *Pholis laeta*, *Ammodytes hexapterus*, and *Oncorhynchus* sp.

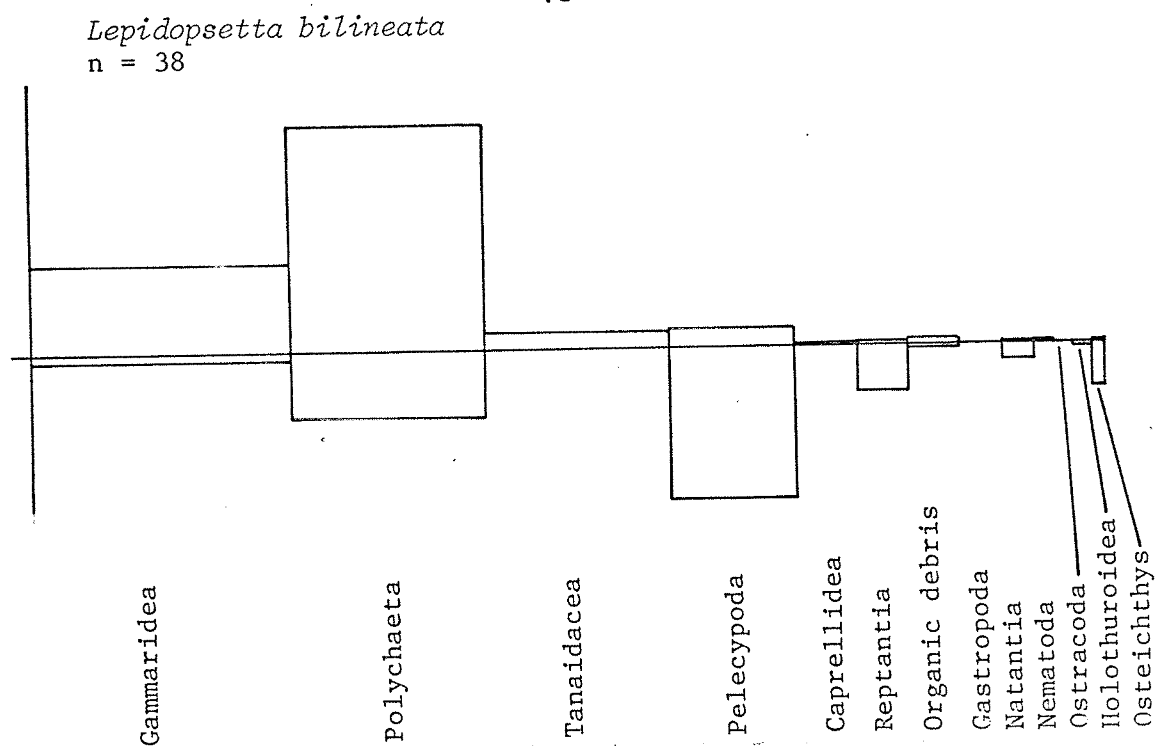


Fig. 22. Composite prey spectrum of rock sole in Strait of Juan de Fuca, May 1976 - January 1977.

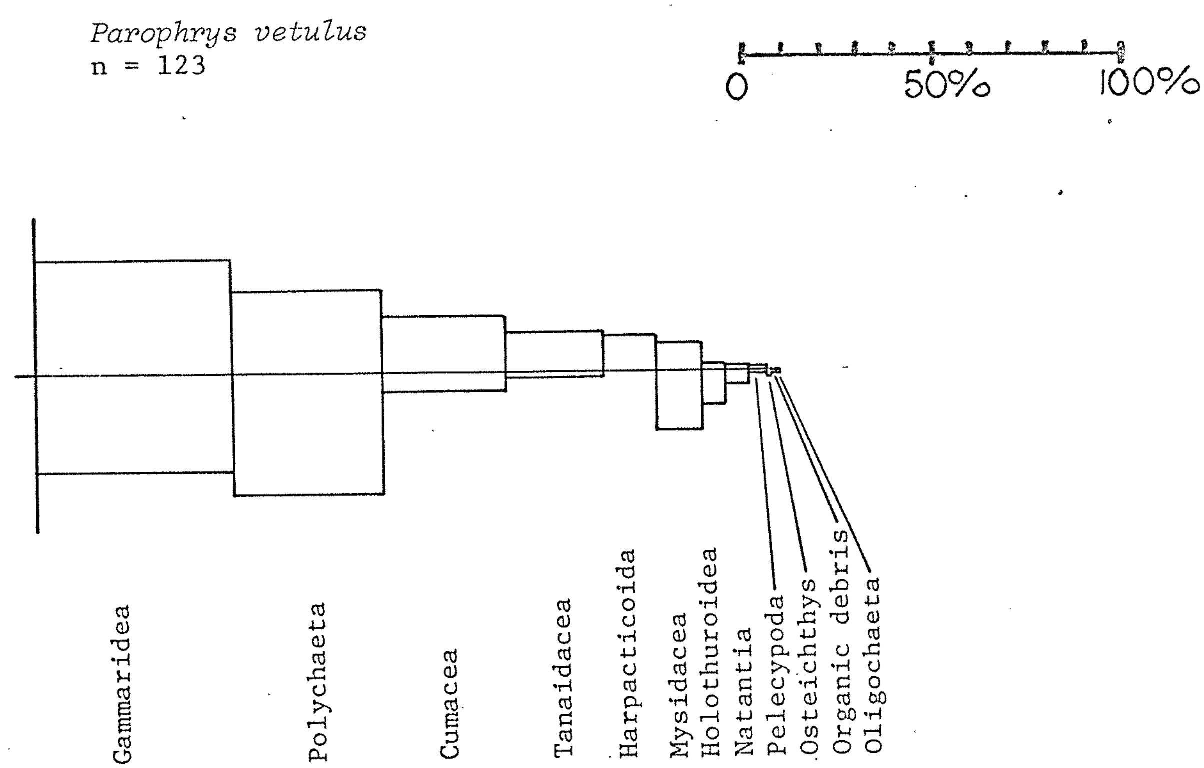


Fig. 23. Composite prey spectrum of English sole in Strait of Juan de Fuca, May 1976 - January 1977.

Parophrys vetulus, English Sole

English sole, principally juveniles, were the most abundant fish in beach seine collections at moderately exposed and protected sites; they were noticeably more abundant during the summer. Their stomachs averaged a little less than half full and the contents were half identifiable.

Gammarid amphipods, polychaetes, cumaceans, tanaids, harpacticoids, and mysids, in that order, were the most frequently consumed prey and made the same general contribution to numerical and gravimetric percentage composition (Fig. 23). Other prey items of importance were isopods (*Synidotea nubulosa* and sphaeromatid species), holothurians, shrimp (*Crangon* spp.), and pelecypods and pelecypod parts (clam siphons).

Variation in prey composition by season were evident (Table 15). Gammarid amphipods and cumaceans gradually declined in importance from spring to winter; tanaids also declined from spring through autumn but increased to the second most important prey taxon in winter. Polychaetes made a significant contribution to the diet but generally dominated in the autumn and winter. Holothurians appeared in the diet as an important prey item only in autumn and winter.

Platichthys stellatus, Starry Flounder

Starry flounder were encountered at all beach seine sites along the Strait of Juan de Fuca but were more abundant at Jamestown, Twin Rivers, and Beckett Point. Approximately one-third of the stomach samples originated from juvenile fish. Thirty-six percent of the total sample had empty stomachs; the remainder averaged 25 percent full and less than 50 percent of the stomach contents were identifiable.

Polychaetes were the most common prey organism in the prey spectrum of *P. stellatus* and contributed the majority to the prey biomass (Fig. 24). Gammarid amphipods, however, provided more individuals to the overall

Table 15. Dominant prey items by season of English sole captured by beach seine and townet in the Strait of Juan de Fuca, May 1976–January 1977.

	% frequency of occurrence	% Composition	
		Abundance	Biomass
Spring (May) n = 21			
Gammarid amphipods	81	18.39	19.83
Tanaids	67	30.36	18.17
Cumaceans	52	19.22	20.52
Polychaetes	43	8.36	24.56
Harpacticoid copepods	38	10.86	0.25
Shrimp larvae	33	6.69	9.55
Shrimp	10	1.11	0.95
Mysids	5	2.79	2.86
Clam siphons	5	0.28	0.64
H' (abundance) = 2.95			
H' (biomass) = 3.03			
Summer (August) n = 50			
Gammarid amphipods	68	40.89	44.39
Cumaceans	50	20.01	7.89
Polychaetes	30	10.51	19.87
Mysids	18	5.99	15.45
Tanaids	16	5.85	1.03
Harpacticoid copepods	14	12.83	0.24
Ostracods	10	0.40	0.26
Clams	8	0.67	0.46
Clam siphons	6	0.20	0.06
Isopods	4	0.61	1.42
Fish	2	0.07	4.24
H' (abundance) = 2.84			
H' (biomass) = 2.87			
Fall (October) n = 14			
Polychaetes	50	25.22	30.18
Gammarid amphipods	21	3.97	2.55
Mysids	14	22.38	33.04
Holothurians	14	13.36	29.62
Cumaceans	14	3.25	1.36
Decapod eggs	7	28.88	0.88
Clam siphons	7	0.72	0.32
Isopods	7	0.72	0.16
Shrimp	7	0.36	0.72
H' (abundance) = 2.81			
H' (biomass) = 2.55			

Table 15, cont'd

	% Frequency of occurrence	% Composition	
		Abundance	Biomass
Winter (January) n = 35			
Polychaetes	51	52.69	51.41
Tanaids	26	11.09	2.50
Gammarid amphipods	17	18.11	8.58
Mysids	17	7.18	8.14
Holothuroideans	11	3.43	10.27
Cumaceans	6	1.14	0.15
Shrimp	3	0.16	11.72
Clam siphons	3	0.16	0.05
Oligochaetes	3	1.14	3.48
H' (abundance) = 3.23			
H' (biomass) = 3.13			

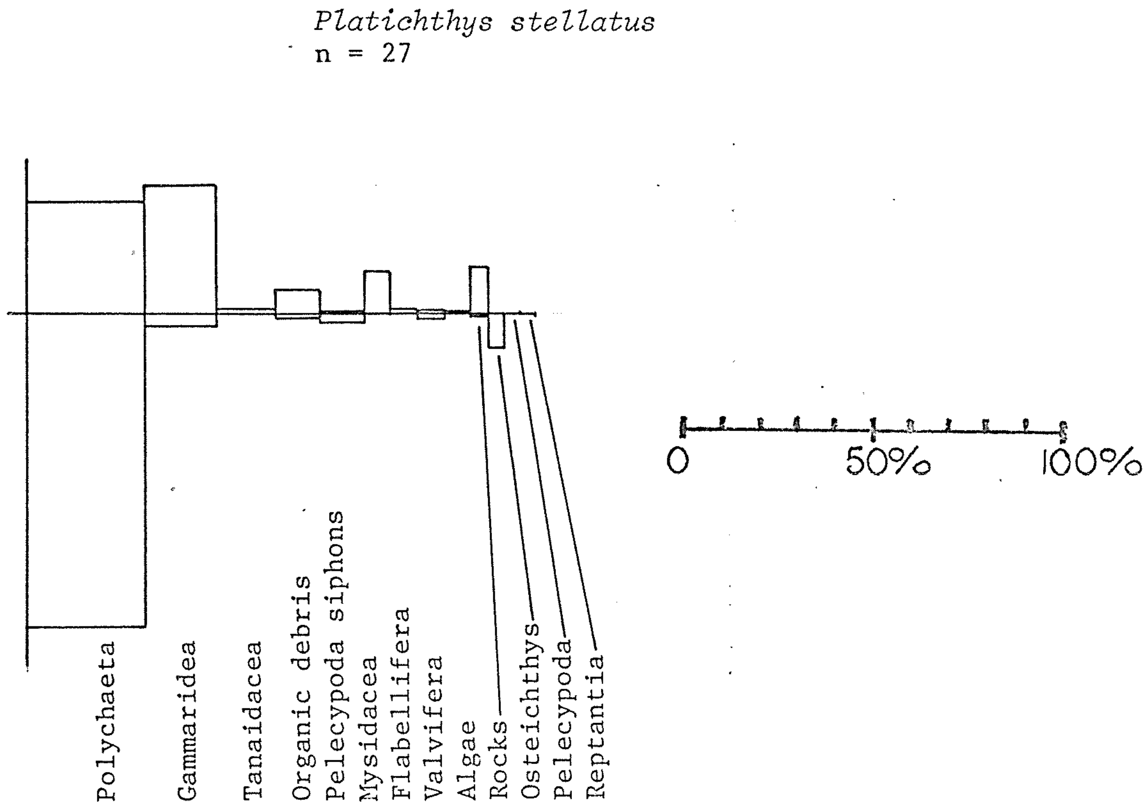


Fig. 24. Composite prey spectrum of starry flounder in Strait of Juan de Fuca, May 1976 - January 1977.

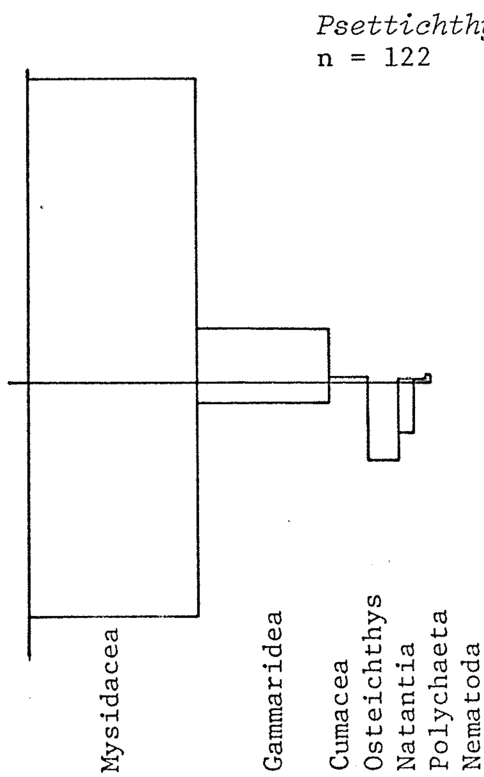


Fig. 25. Composite prey spectrum of sand sole in Strait of Juan de Fuca, May 1976 - January 1977.

diet. Other important prey included mysids, fish (Pholidae, Gobiesocidae, Hexagrammidae), clams (*Clinocardium nuttallii*) and clam siphons, isopods, and anomuran crabs (*Pagurus hirsutiusculus*, Pinnotheridae).

Pleuronichthys coenosus, C-O Sole

Beach seine collections at Beckett Point in May and January provided the stomach samples of adult C-O sole. Polychaetes were by far the dominant prey, occurring in 83 percent of the stomachs and composing 78.5 percent of the total prey and 79.5 percent of the total biomass. Gammarid amphipods and clam siphons both occurred in 58 percent of the sample providing 6.2 percent and 2.8 percent of the total prey abundance and 1.7 percent and 4.5 percent of the prey biomass, respectively. Tanaids, intact clams, and gastropods also occurred frequently in the stomach but contributed little to the prey composition. A saddleback gunnel, *Pholis ornata*, in one stomach constituted 8.8 percent of the total contents biomass. Organic detritus, including pieces of eelgrass (*Zostera*) also occurred in 25 percent of the stomach samples.

Psettichthys melanostictus, Sand Sole

Sand sole, over 80 percent of which were juveniles, were present in the beach seine collections throughout the year. They occurred at all sampling locations but tended to be most abundant at the Dungeness Spit and Twin Rivers sites. Only 6 percent of the total sample contained empty stomachs, the others averaged close to 75 percent full and just over 50 percent of the contents were identifiable.

The overall prey spectrum (Fig. 25) shows mysids (*Neomysis* sp.) to be the primary prey organism; gammarid amphipods were taken almost as frequently but did not make as large a contribution to either the total prey numbers or biomass. Fish (including *Ammodytes hexapterus*) and caridean shrimp (including *Pandalus danae* and other species of Pandalidae, Crangonidae, and Hippolytidae) also contributed significantly to the total prey biomass.

Sand sole prey spectra from the four quarterly samples (Table 16) indicate shifts between the two primary food organisms, mysids and gammarid amphipods, and changes in general spectrum diversity. Winter and spring diets contained more mysids and gammarids than summer and autumn diets. Summer prey composition was diversified by more frequent predation upon fish. Autumn diets exhibited an even more diverse prey spectrum, especially by biomass, because of increased predation upon shrimp and several other prey organisms.

III-H-3. Functional Feeding Groups

The 60 nearshore fish species examined for stomach contents were categorized into eight functional feeding groups (Table 17). Forty-two percent of these species (25) were "facultative planktivores" with diets based on epibenthic organisms and, to a lesser extent, benthic prey. Twenty-seven percent (16) were "obligate planktivores" which prey solely upon epibenthic organisms. In both of these feeding categories, gammarid amphipods and mysids were the principal prey taxa. Five species, considered "facultative benthic feeders," fed predominantly upon benthic prey, principally polychaetes, crabs, clams, and clam siphons, and secondarily consumed epibenthic organisms. Five species of facultative planktivores were present in the neritic fish assemblages, and, accordingly, their diet was made up mostly of neritic plankton, almost exclusively calanoid copepods, and some epibenthic organisms.

Obligate planktivores in the neritic assemblages and "obligate benthic feeders" among the nearshore demersal fishes included only two species each. One facultative planktivore fed on epibenthic plankton and secondarily upon neritic plankton. One species was a high-level predator, an "obligate piscivore," which fed solely upon fishes.

III-H-4. Habitat/Site Differences

Differences in food habits of fishes between the seven sites are difficult to interpret based on this initial survey. Generally, any

Table 16. Dominant prey items by season of sand sole captured by beach seine in the Strait of Juan de Fuca, May 1976 - January 1977.

	% Frequency of occurrence	% Composition Abundance	% Composition Biomass
Spring (May) n = 25			
Gammarid amphipods	100	56.05	38.22
Mysids	88	28.10	44.56
Cumaceans	48	8.22	2.67
Tanaids	12	1.49	0.27
Fish	12	0.75	1.44
Polychaetes	8	0.60	0.37
Shrimp	4	0.30	11.61
H' (abundance) = 1.84			
H' (biomass) = 1.89			
Summer (August) n = 28			
Mysids	29	93.86	49.08
Gammarid amphipods	29	3.48	1.39
Fish	25	1.07	36.12
Shrimp	14	0.98	13.25
H' (abundance) = 1.18			
H' (biomass) = 2.79			
Fall (October) n = 27			
Mysids	56	66.74	48.35
Gammarid amphipods	15	3.62	7.58
Tunicates	7	1.36	0.04
Shrimp	4	3.85	37.30
Fish	4	0.23	6.00
Nematodes	4	15.61	0.09
Calanoid copepods	4	1.81	0.22
Tanaids	4	1.36	0.14
H' (abundance) = 2.62			
H' (biomass) = 2.90			
Winter (January) n = 42			
Mysids	36	95.65	98.48
Gammarid amphipods	10	1.95	0.33
H' (abundance) = 2.60			
H' (biomass) = 2.33			

Table 17. Feeding classifications of sixty species of nearshore fish examined from collections in the Strait of Juan de Fuca, May 1976 - January 1977.

Functional group	Feeding realm	Predators	Principal prey organisms
Neritic Fish Assemblage (tow net)			
Obligate planktivore	Neritic	*Clupea harengus pallasi* juvs.*	Calanoid copepods
		*Ammodytes hexapterus**	Crab zoea
			Mysids
			Larvaceans
			Hyperiid amphipods
			Insects
			Ctenophores
Facultative planktivore	Neritic	*Engraulis mordax*	Calanoid copepods
	Epibenthic	*Oncorhynchus gorbuscha* juvs.*	Harpacticoid copepods
		O. tshawytscha juvs.	Mysids
		*Hypomesus pretiosus**	Gammarid amphipods
		*Spirinchus thaleichthys**	Cumaceans
Nearshore Demersal Fish Assemblage (beach seine)			
Obligate benthic feeder	Benthic	*Porichthys notatus*	Polychaetes
		Scorpaenichthys marmoratus	Crabs
			Clams
			Clam siphons
			Fish
Obligate planktivore	Epibenthic	*Raja binoculata*	Gammarid amphipods
		R. abyssicola	Caridean shrimp
		R. stellulata	Mysids
		Oncorhynchus keta juvs.*	Harpacticoid copepods
		O. kisutch juvs.	Cumaceans
		Salmo gairdneri juvs.	Tanaids
		Syngnathus griseolineatus	Leptostracans
		*Blepsias cirrhosus**	Caprellid amphipods

*Species with significant sample sizes.

Table 17, cont'd

Functional group	Feeding realm	Predators	Principal prey organisms
		Myoxocephalus polyacanthocephalus juvs.	
		Occella verrucosa	
		Pallasina barbata	
		*Agonus acipenserinus**	
		Liparis callyodon	
		L. pulchellus	
		Trichodon trichodon	
		Eopsetta jordani	
Facultative benthic feeder	Benthic	*Lepidopsetta bilineata**	Polychaetes
	Epibenthic	*Parophrys vetulus* juvs.*	Crabs
		*Platichthys stellatus**	Clam siphons
		Pleuronichthys coenosus	Clams
		Lumpenus sagitta	Gastropods
			Gammarid amphipods
			Mysids
			Tanaids
			Fishes
			Harpacticoid copepods
Facultative planktivore	Epibenthic	*Squalus acanthias*	Gammarid amphipods
	Benthic	*Gadus macrocephalus* juvs.	Caridean shrimp
		*Microgadus proximus**	Mysids
		Theragra chalcogrammus juvs.*	Harpacticoid copepods
		*Aulorhynchus flavidus**	Cumaceans
		*Hexagrammos stelleri**	Tanaids
		*Artedius fenestralis**	Polychaetes
		*Ascelichthys rhodorus**	Crabs
		*Clinocottus acuticeps**	Fish
		Enophrys bison(?)*	Calanoid copepods

*Species with significant sample sizes.

Table 17, cont'd

Functional group	Feeding realm	Predators	Principal prey organisms
		*Leptocottus armatus**	
		Chitonotus pugetensis	
		Liparis cyclopus	
		L. florae	
		L. mucosus	
		*Cymatogaster aggregata**	
		*Embiotoca lateralis**	
		*Rhacochilus vacca**	
		*Amphistichus rhodoterus**	
		Apodichthys flavidus	
		Pholis laeta	
		P. ornata	
		Citharichthys stigmaeus	
		C. sordidus	
		Psettichthys melanostictus juvs.*	
Facultative planktivore	Epibenthic Neritic	*Gasterosteus aculeatus*	Harpacticoid copepods Gammarid amphipods Calanoid copepods
Obligate piscivore	Benthic Epibenthic	*Ophiodon elongatus*	Fish

*Species with significant sample sizes.

particular nearshore demersal fish species was not abundant at more than one or two sites; the major neritic species, on the other hand, were rather ubiquitous. There were associations between certain prey taxa and the sites where fish were found to have utilized them. For example, mysids were prevalent in nearshore demersal fish species at Twin Rivers; shrimp and crabs were common food items for species at Beckett Point and Morse Creek; and polychaetes and clams (including clam siphons) were the most frequently utilized prey organisms at Jamestown. Gammarid amphipods were prevalent in fish prey spectra from all sites. Similarly, calanoid copepods were well-represented in the diets of neritic species captured at all seven townet sites. Other less important neritic food items were unique to certain sites, such as euphausiids at Twin Rivers and shrimp and crab larvae at Beckett Point.

Without knowing the relative distributions and abundances of nearshore invertebrates characterizing these sites, we cannot suggest that certain species are necessarily inhabiting an area because of specific prey organisms. The only information available was the catalogue of macroinvertebrates compiled from beach seine data. Although the seine is not designed to quantitatively sample fish food items (the 0.6-cm mesh in the bag retained only the larger epibenthic organisms), the data indicate the invertebrate species richness and character of the sites which may be indicative of the availability of prey organisms for the nearshore fish. The best example is Beckett Point where caridean shrimp, isopods, and brachyuran crabs were most abundant in beach seine collections. All life-history stages of these organisms also appeared in the stomachs of many of the dominant nearshore demersal fish species inhabiting Beckett Point (i.e., juvenile Pacific tomcod, juvenile walleye pollock, tubesnout, staghorn sculpin, roughback sculpin, great sculpin, cabezon, rock, C-O sole, and starry flounder.

IV. CONCLUSIONS

IV-A. Nearshore Fish Assemblages

The data compiled in this report were collected during the first year of a multi-year effort. The conclusions presented here are based upon one set of replicate samples from every site during each of the four seasons; they may be regarded as preliminary until further data are available. With succeeding years of data collection, more conclusions can be formulated and those presented here can be verified or altered.

The nearshore demersal fish fauna of the Strait of Juan de Fuca exhibits a variety of overlapping distributions based upon habitat, exposure, geography, and other undetermined factors. Specific assemblages, e.g., habitat specific or exposure specific, are thus difficult to define. The neritic fish fauna is not as species-rich as the demersal fauna and is dominated by one species (Pacific herring). The remaining neritic species are distributed in a variety of overlapping patterns similar to those observed in the demersal fauna.

The effect of an oil spill on the nearshore demersal and neritic fish fauna is unlikely to be clear cut. Neritic species, e.g., herring, smelt, salmonids, which regularly range over large areas, possess the capabilities as adults of leaving or avoiding polluted water, but as juveniles or spawning adults may be restricted to the nearshore area and unable to avoid polluted water. Demersal fish, e.g., English sole, sand sole, greenling, are more limited in their movements during all life-history stages and may not be able to move away from a polluted area.

The severity of the effects of pollution are also dependent upon the area where the oil occurs, i.e., different habitats will be affected differently. Oil is less likely to remain in areas with high rates of flushing, e.g., exposed, sandy beaches, than in protected embayments. Exposed areas possess fewer species of macroinvertebrates and fishes than protected areas and are thus less likely to be severely affected.

The impact of an oil spill will also be determined by the time of year in which it occurs. Oil spills in the nearshore environment during the winter, when most fish have moved into deeper water, will produce fewer adverse effects than those occurring during the summer, when fish have moved back into shallow water. This is further complicated by the fact that, for many demersal species, nearshore areas are nursery grounds for recently settled larvae, e.g., English sole sand sole. All beach seine sites along the Strait of Juan de Fuca were utilized by juvenile fishes.

The specific effects of hydrocarbons on individual fish have not been cited as, for the most part, they are unknown. Various fractions of unrefined oil have been shown to be more or less toxic to marine organisms in laboratory experiments (e.g., Powell et al. 1970), but the in situ effects are little known (Straughan 1976). In addition to being directly toxic to an organism, hydrocarbons may affect any of a number of processes vital to the continued existence of its genes. For example, hydrocarbons may affect the ability of migrating fish to locate the area, be it feeding territory, spawning ground, etc., which they seek. Hydrocarbons could also affect the ability of sexual pheremone perception, shown to be a necessary component of successful reproduction in some fishes. They could also affect the feeding ability of some fish if their prey were adversely affected (the prey could be reduced in numbers if the effects were lethal, or, if the prey accumulated oil residues, they could be potentially toxic to the predator, although results to date are equivical (Straughan 1976).

IV-B. Associated Macroinvertebrates

Neither the beach seine nor the townet was designed to sample macroinvertebrates quantitatively; therefore, the conclusions which can be drawn from the cataloguing of macroinvertebrates are limited. In addition, the efficiency of recovering the invertebrates from the net varied according to the quantity of fish and algae in the catch. Given the high abundance of fish captured at sites such as Beckett Point, invertebrate collections were often difficult to obtain in a consistent manner. Thus, other than an indication of the occurrence of common species (Appendix 6), little quantitative information is available and estimates of densities, standing crop, sex ratios, and number of gravid females are not reliable measures of the nearshore macroinvertebrate assemblages.

Few species were found consistently year-round at any one site. This may be a sampling bias but could also be attributed to a seasonal inshore-offshore movement or patchy distributions of the organisms.

As in the case of the nearshore fish assemblages, a decrease in macroinvertebrates (number of species and individuals) appears to be correlated with increasing exposure. Beckett Point, the most protected site, was characterized by a species-rich algal and eelgrass macroinvertebrate community. Dungeness Spit and Kydaka Beach, on the other hand, are exposed to high wave action, have clean, unstable sand beaches, and support a comparatively species-poor community.

IV-C. Nearshore Food Web Structure

When relating the food spectra of the various nearshore fish species to the possible effects of pollutant influx into the nearshore region, it is important to evaluate the status of the fish species and its life-history stage during its residence in the nearshore environs. Most of the dominant neritic species--juvenile Pacific herring, Pacific sand lance, surf and longfin smelt--depend upon pelagic plankton as principal food organisms, which are both less available to toxic elements of petroleum hydrocarbons and less widely distributed. Nearshore demersal species, on the other hand, are typically more dependent upon epibenthic and truly benthic organisms, which are confined to certain nearshore habitats. Fish associated with a particular nearshore habitat may occur there because of the types or sizes of prey organisms. For example, juvenile salmonids (specifically chum salmon) and flatfish (English sole) spend a high percentage of their early marine life history in the shallow sublittoral zone feeding upon epibenthic plankton--harpacticoid copepods, gammarid amphipods, cumaceans, tanaids, and polychaetes. And, while the fish themselves may be relatively insensitive to the pollutant or actually avoid it (Rice 1973), infaunal and epifaunal invertebrates may be more sensitive and do not have the ability to move away from a pollutant.

Not only are these prey organisms limited to an area where an oil spill would impose an immediate (acute) effect (Sanders et al. 1971; Chan 1972; Hann 1975; and others), but the littoral and shallow sublittoral sediments tend to retain and accumulate oil (Burns and Teal 1971) providing a continuous (chronic) source of petroleum hydrocarbons for transfer into the food web (Blumer et al. 1970, Krebs and Burns 1977) or disruption of the community structure through sublethal effects.

It is not known whether the reduction or elimination of a primary prey organism will result in the predator switching to another, less-preferred prey. Fish prey upon a particular organism because it provides them with a net energy gain over energy expended; an alternative prey may not provide a net energy gain. Assuming alternate prey are more costly to the predator (e.g., because they are harder to locate, there are fewer of them, or they yield less energy), the fish may suffer higher mortalitites (e.g., more susceptible to predators), lowered reproductive success, lowered growth rates, etc. Unfortunately, we have no quantitative evidence of the thresholds and costs involved in such switching.

Of the principal nearshore fish species inhabiting the Strait of Juan de Fuca shoreline, 42 percent were classed as obligate planktivores, facultative benthivores, or facultative planktivores dependent upon benthic and/or epibenthic prey organisms of the shallow sublittoral zone. Many of these--juvenile chum and coho salmon, juvenile steelhead, rock sole, juvenile English sole, C-O sole (*Pleuronichthys coensus*), starry flounders, juvenile Pacific cod, juvenile walleye pollock, greenling, lingcod--are economically important or are themselves prey for economically important species. The influx of significant amounts of hydrocarbon, whether short-term or long-term, could result in a disruption of the populations of prey organisms which the nearshore fishes utilize and the transfer of the pollutant from prey tissues to predator tissues.

IV-D. Contributions To Knowledge

This study is the first systematic sampling effort designed to survey the nearshore fish fauna along the Strait of Juan de Fuca. Data on distribution, abundance, and biomass of fish and macroinvertebrates are a unique and significant contribution to the biological knowledge of the nearshore fish community of the Strait of Juan de Fuca. This study also represents an important extension of the data on the nearshore fish fauna of Puget Sound, Rosario Strait, and the San Juan archipelago. The nearshore fish section of the MESA Puget Sound Project is the most comprehensive effort in this area to date to determine the food habits of the nearshore fish and to identify the macroinvertebrates collected with the fish.

IV-E. Recommendations

1. Data should be gathered over a period of several years to properly assess seasonal trends and inter-year variations.

2. Scuba surveys and/or trammel netting could be conducted in rocky/kelp bed areas to determine species present there but not susceptible to the beach seine or townet.

3. Purse seining could be conducted to sample adult pegalic fish capable of avoiding the townet.

4. Diel sampling could be conducted to determine the 24-hour variation in composition of the fish fauna at specific sites.

5. Bioassays could be conducted on specific life-history stages of abundant or economically important species to determine sensitivity to hydrocarbon pollution.

6. Nearshore ichthyoplankton sampling could be conducted to determine larval species present in nearshore waters as a supplement to the offshore ichythyoplankton work.

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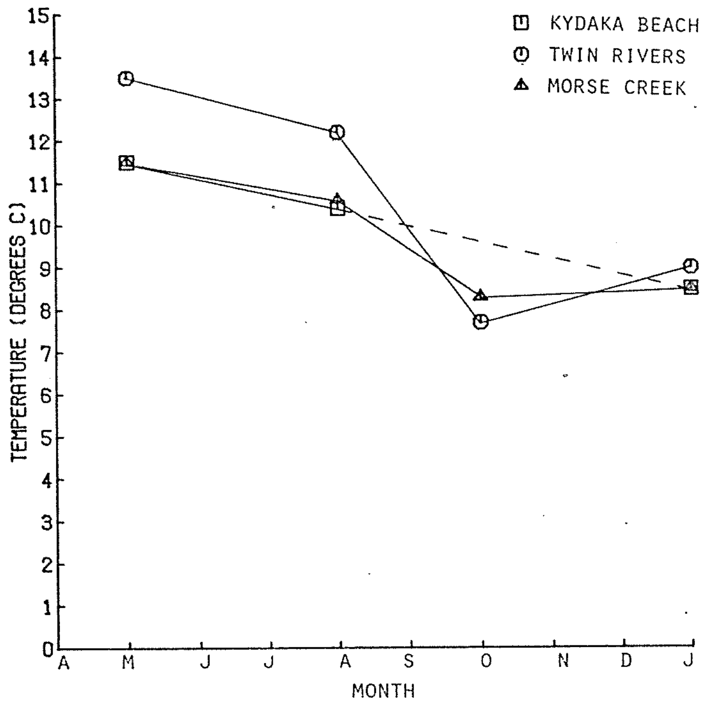
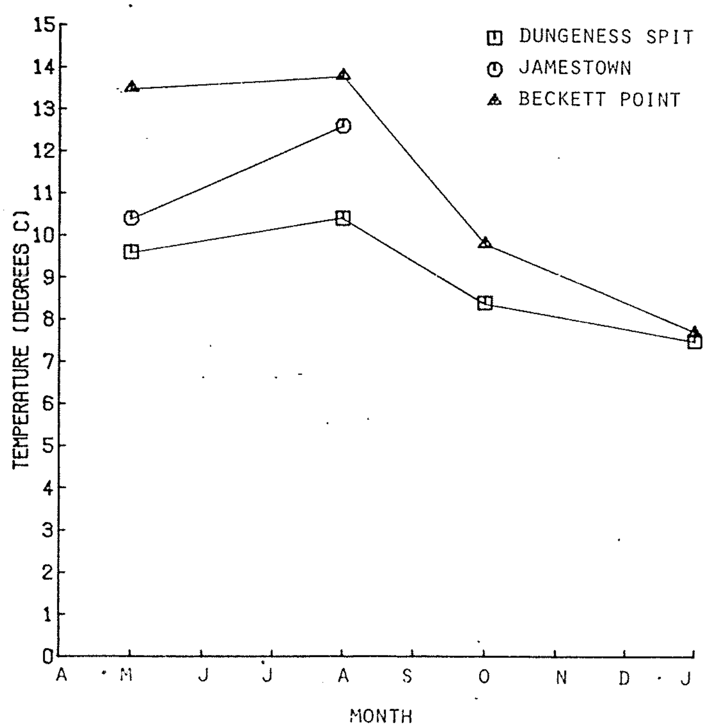
APPENDIX 1

OCEANOGRAPHIC DATA FROM BEACH SEINE AND TOWNET COLLECTIONS

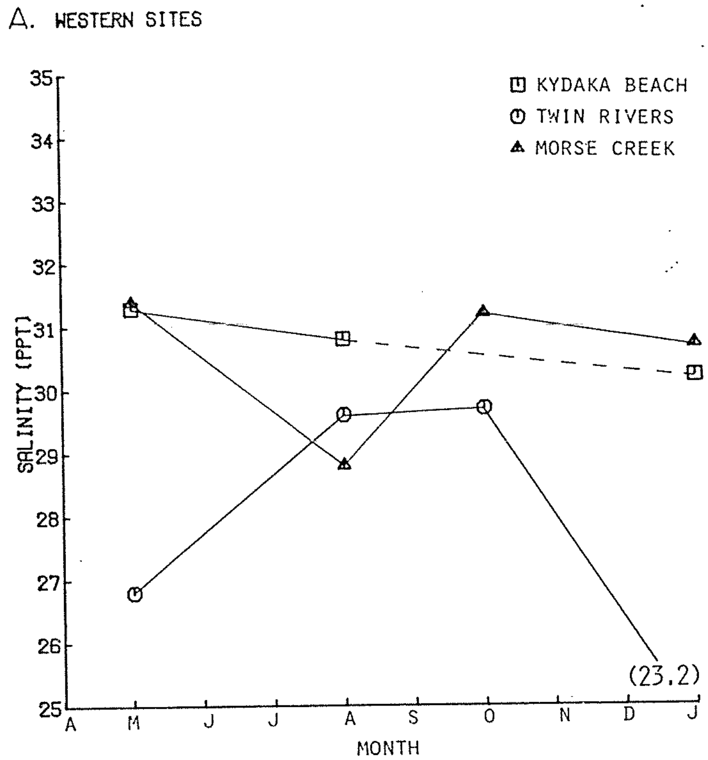
A. WESTERN SITES

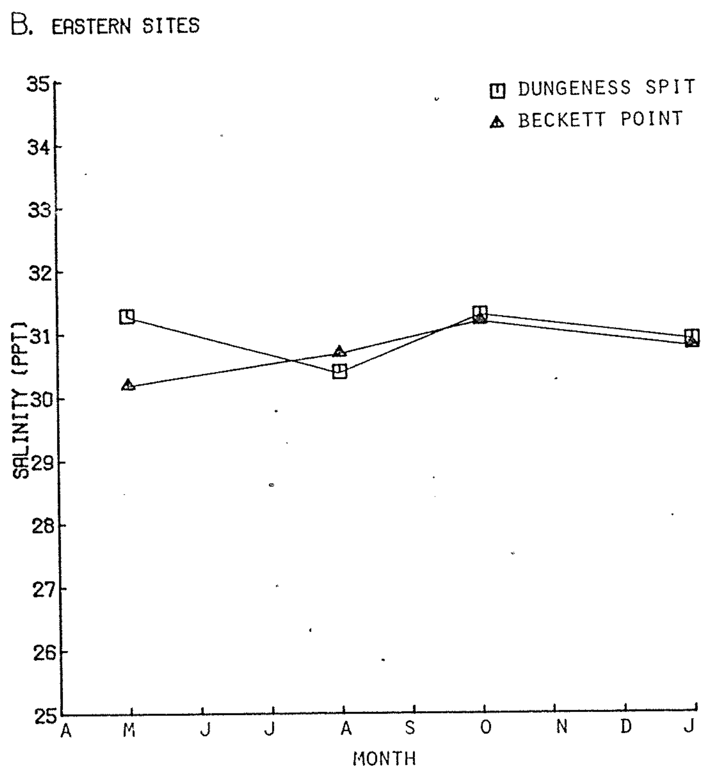


B. EASTERN SITES

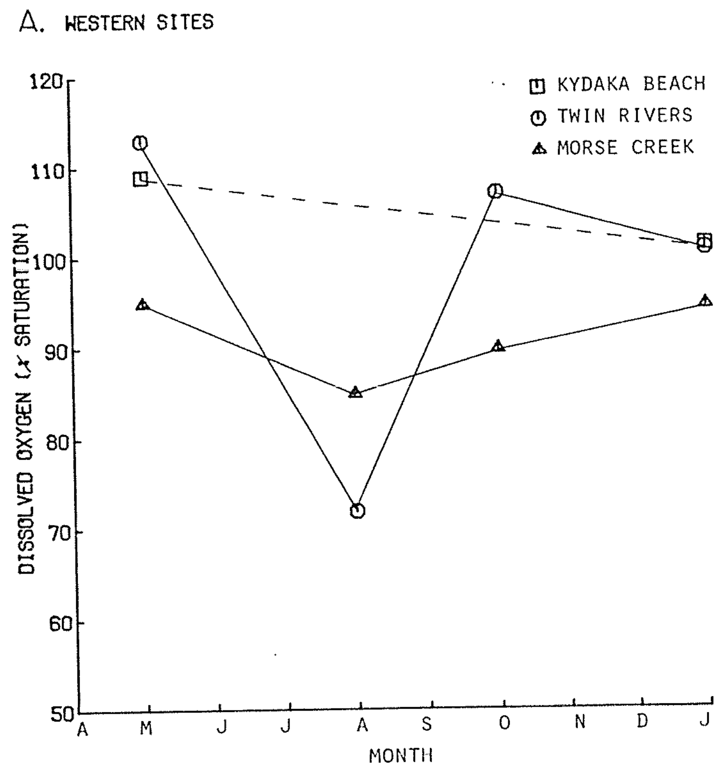


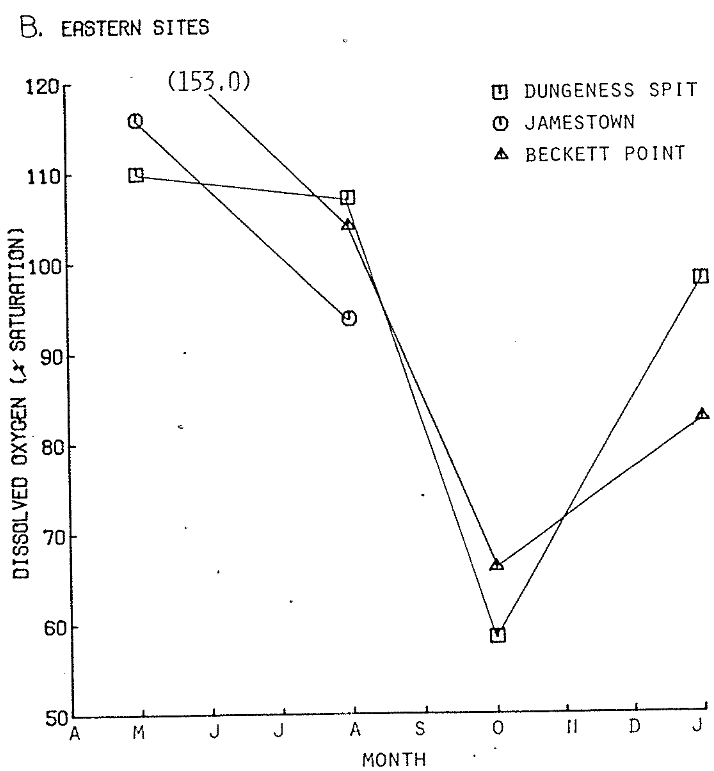
Appendix 1-a. Nearshore surface water temperature (°C) for western sites (A) and eastern sites (B) as recorded during quarterly beach seine collections in the Strait of Juan de Fuca.





Appendix 1-b. Nearshore surface water salinity (ppt) for western sites (A) and eastern sites (B) as recorded during quarterly beach seine collections in the Strait of Juan de Fuca.





Appendix 1-c. Nearshore surface water dissolved oxygen (% saturation) for western sites (A) and eastern sites (B) as recorded during quarterly beach seine collections in the Strait of Juan de Fuca.

Appendix 1-d. Beach seine temperature summary.

Location	Spring	Summer	Autumn	Winter	$\bar{x}$	S.D.
Kydaka Beach	11.5	10.4	--	8.5	10.1	1.24
Twin Rivers	13.5	12.2	7.7	9.0	10.6	2.34
Morse Creek	11.5	10.6	8.3	8.5	9.7	1.36
Dungeness Spit	9.6	10.4	8.4	7.5	9.0	1.11
Jamestown	10.4	12.6	--	--	11.5	1.10
Beckett Point	13.5	13.8	9.8	7.7	11.2	2.56
$\bar{x}$	11.7	11.7	8.6	8.2		
SD	1.45	1.29	0.77	0.56		

Appendix 1-e. Beach seine salinity summary.

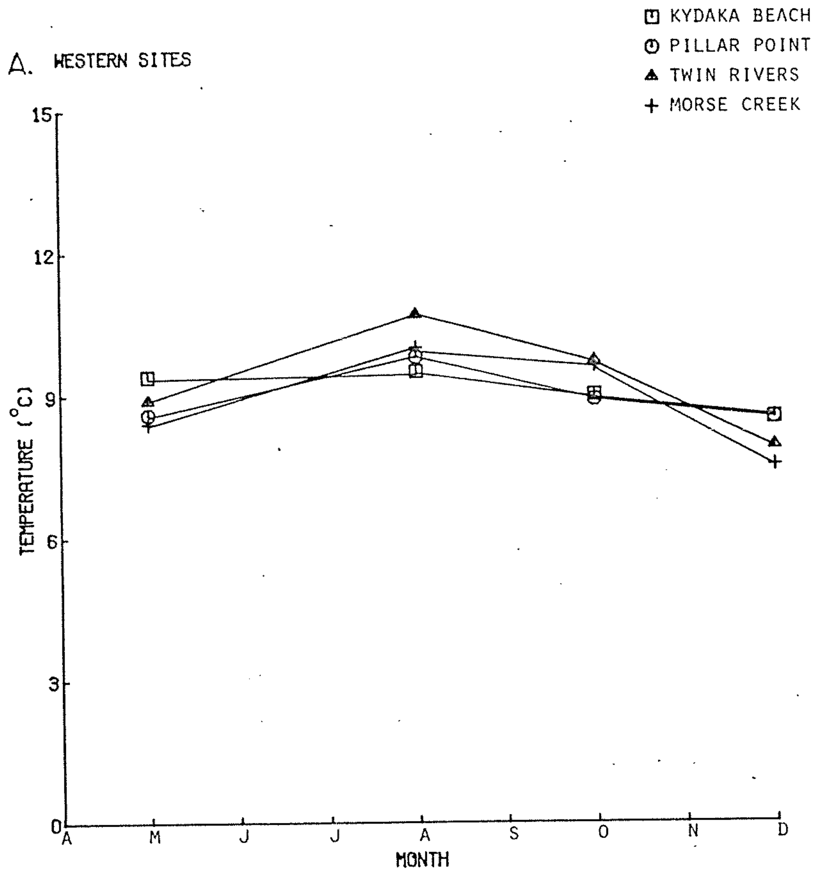
Location	Spring	Summer	Autumn	Winter	$\bar{x}$	S.D.
Kydaka Beach	31.3	30.8	--	30.2	30.8	0.45
Twin Rivers	26.8	29.6	29.7	23.2	27.3	2.65
Morse Creek	31.4	28.8	31.2	30.7	30.5	1.03
Dungeness Spit	31.3	30.4	31.3	30.9	31.0	0.37
Beckett Point	30.2	30.7	31.2	30.8	30.7	0.36
$\bar{x}$	30.2	30.1	30.9	29.6		
SD	1.76	0.76	0.67	2.99		

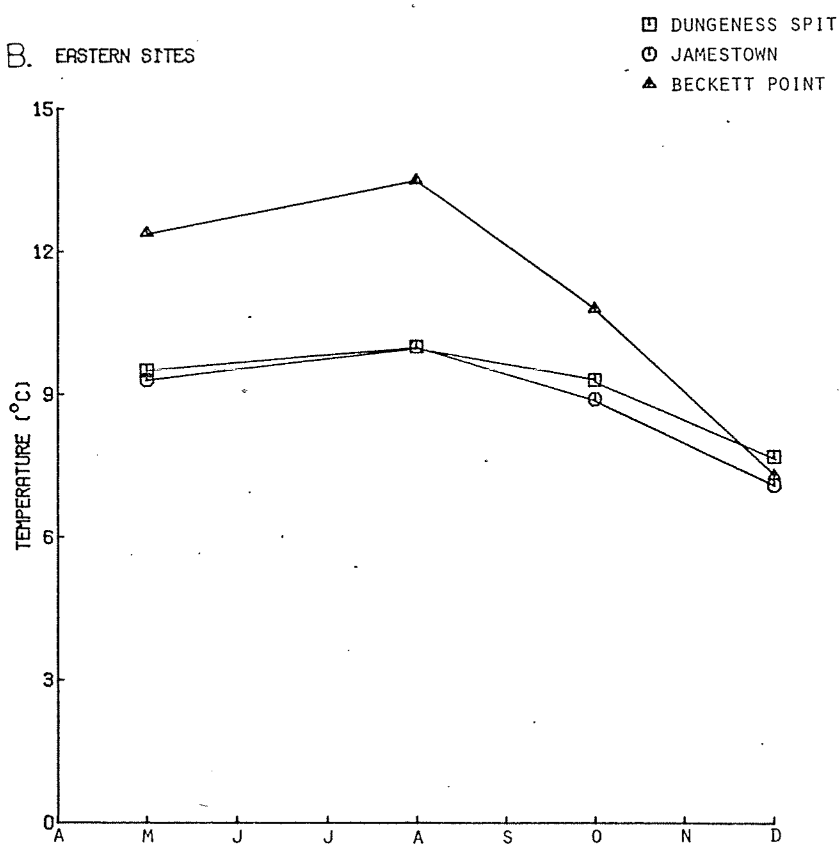
Appendix 1-f. Beach seine dissolved oxygen summary.

Location	Spring	Summer	Autumn	Winter	$\bar{x}$	SD
Kydaka Beach	109.0	--	--	101.3	105.2	3.90
Twin Rivers	113.0	71.9	107.1	100.8	98.2	15.79
Morse Creek	95.0	84.9	89.8	94.5	91.1	4.09
Dungeness Spit	110.0	107.2	58.5	98.0	93.4	20.65
Jamestown	116.0	93.8	--	--	104.9	11.10
Beckett Point	153.0	104.1	66.2	82.6	101.5	32.64
$\bar{x}$	116.0	92.4	80.4	95.4		
SD	17.81	12.92	19.25	6.86		

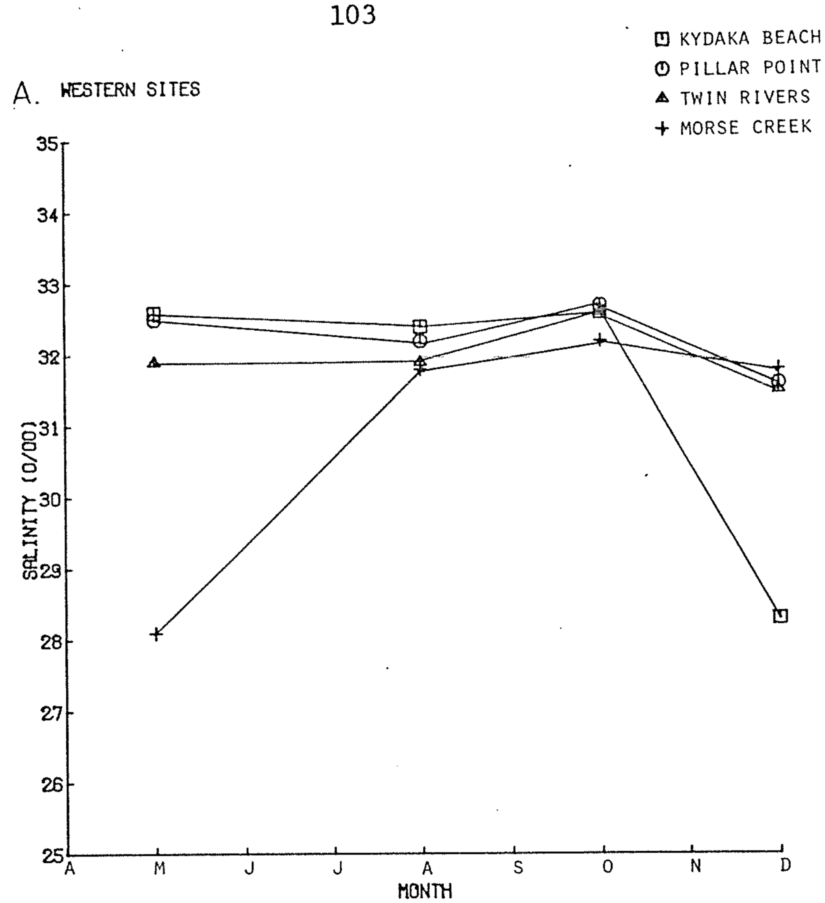
Appendix 1-g. Comparison of the means (over all beach seine collections) of oceanographic data between eastern and western sites.

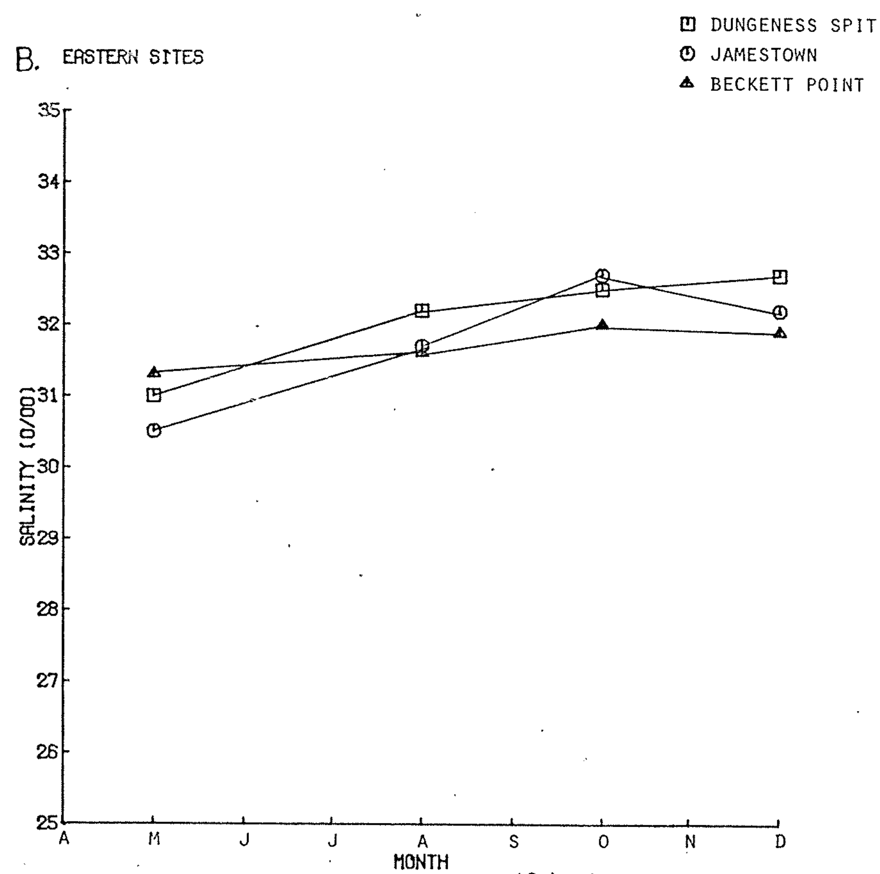
		Western sites	Eastern sites
Temperature	$\bar{x}$	10.2	10.4
(°C)	SD	1.9	2.3
	Min-Max	7.7-13.5	7.5-13.5
	Range	5.8	6.0
Salinity	$\bar{x}$	29.4	30.9
(ppt)	SD	2.5	0.4
	Min-Max	23.2-31.4	30.2-31.3
	Range	8.2	1.1
Dissolved oxygen	$\bar{x}$	96.7	98.4
	SD	12.4	26.7
	Min-Max	71.9-	58.5-153.0
	Range	41.1	94.5



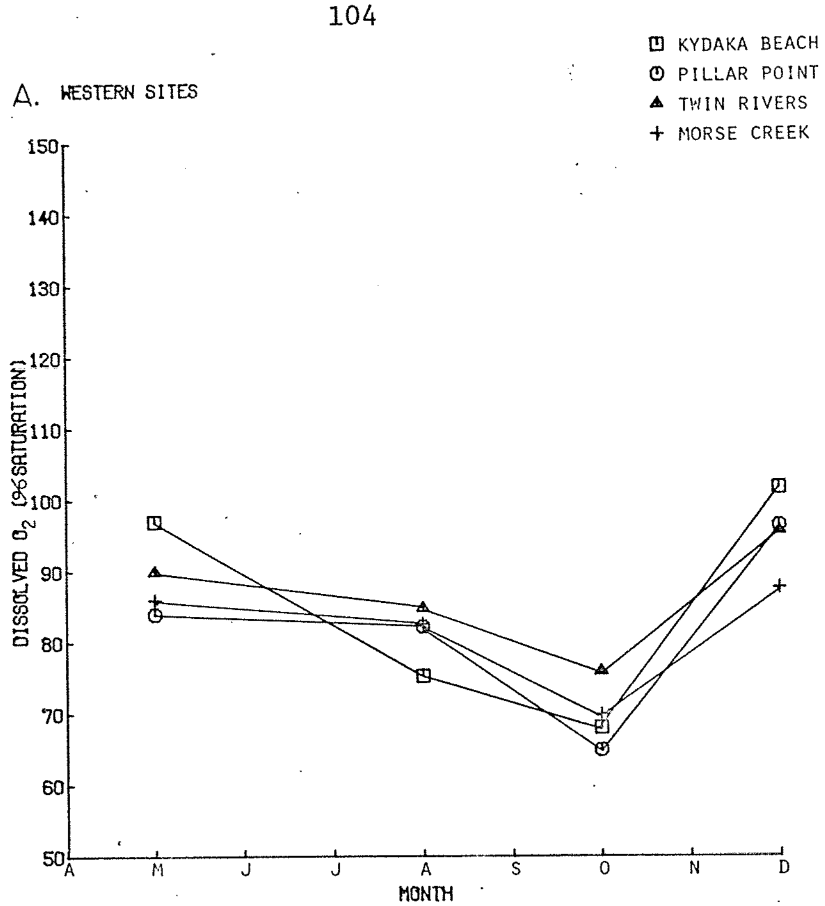


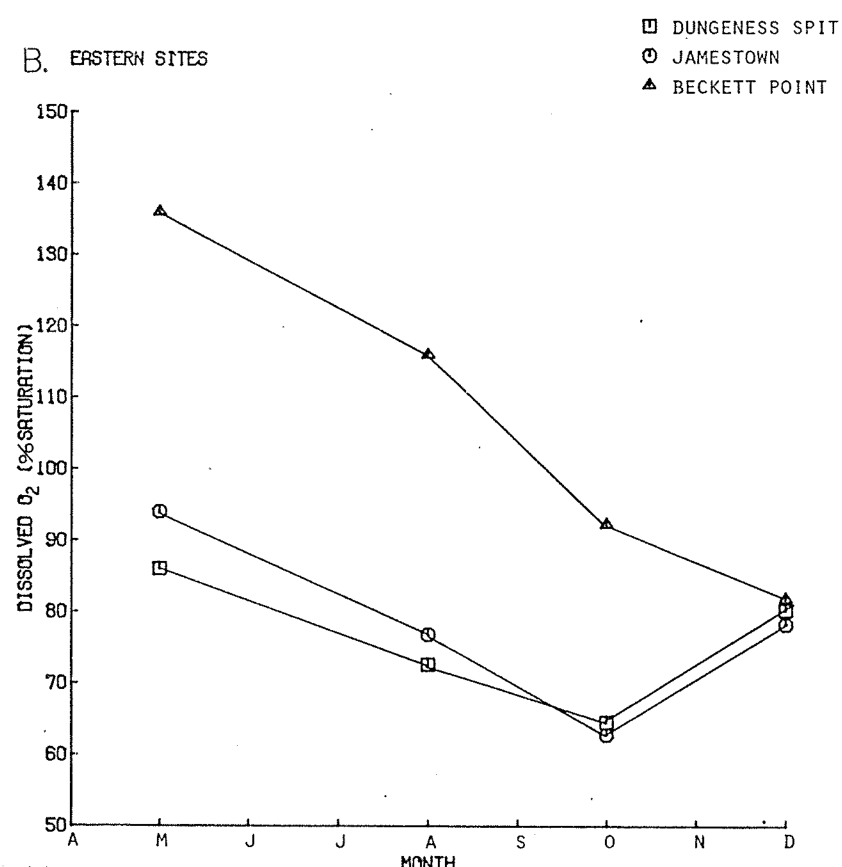
Appendix-1-h. Nearshore surface water temperature (°C), for western sites (A) and eastern sites (B), as recorded during quarterly tow net collections in the Strait of Juan de Fuca.





Appendix-1-i. Nearshore surface water salinity (°/oo), for western sites (A) and eastern sites (B), as recorded during quarterly townet collections in the Strait of Juan de Fuca.





Appendix 1-j. Nearshore surface water dissolved oxygen (% saturation), for western sites (A) and eastern sites (B), as recorded during quarterly townet collections in the Strait of Juan de Fuca.

Appendix 1-k. Summary of nearshore surface water temperature (°C) as recorded during townet collections.

Location	Spring	Summer	Fall	Winter	Mean	SD
Kydaka Beach	9.4	9.5	9.0	8.5	9.1	0.45
Pillar Point	8.6	9.8	8.9	8.5	8.9	0.59
Twin Rivers	8.9	10.7	9.7	7.9	9.3	1.19
Morse Creek	8.4	10.0	9.6	7.5	8.9	1.14
Dungeness Spit	9.5	10.0	9.3	7.7	9.1	.99
Jamestown	9.3	10.0	8.9	7.1	8.8	1.23
Beckett Point	12.4	13.5	10.8	7.3	11.0	2.70
Mean	9.5	10.5	9.5	7.8		
SD	1.34	1.37	0.68	0.55		

Appendix 1-l. Summary of nearshore surface water salinity (°/oo) as recorded during townet collections.

Location	Spring	Summer	Fall	Winter	Mean	SD
Kydaka Beach	32.6	32.4	32.6	28.3	31.5	2.12
Pillar Point	32.5	32.2	32.7	31.6	32.3	0.48
Twin Rivers	31.9	31.9	32.6	31.5	32.0	0.46
Morse Creek	28.1	31.8	32.2	31.8	31.0	1.93
Dungeness Spit	31.0	32.2	32.5	32.7	32.1	0.76
Jamestown	30.5	31.7	32.7	32.2	31.8	0.94
Beckett Point	31.3	31.6	32.0	33.1	31.7	0.32
Mean	31.1	32.0	32.5	31.6		
SD	1.54	0.30	0.27	1.57		

Appendix 1-m. Summary of nearshore surface water dissolved oxygen (% saturation).as recorded during townet collections.

Location	Spring	Summer	Fall	Winter	Mean	SD
Kydaka Beach	97.0	75.3	68.0	101.6	84.5	2.12
Pillar Point	84.0	82.2	64.9	96.3	81.9	0.48
Twin Rivers	90.0	84.8	75.9	95.5	86.6	0.46
Morse Creek	86.0	82.6	69.9	87.6	81.5	1.93
Dungeness Spit	86.0	72.6	64.6	80.3	75.9	0.76
Jamestown	94.0	76.8	62.8	78.3	78.0	0.94
Beckett Point	136.0	116.0	92.3	81.9	106.6	0.32
Mean	96.1	84.3	71.3	88.8		
SD	18.19	14.64	10.27	9.10		

Appendix 1-n. Comparison of the means (over all townet collections) of oceanographic data for eastern and western sites.

		Western sites	Eastern sites
Temperature (°C)	$\bar{x}$	9.06	9.65
	SD	0.83	1.92
	Min-max	7.5-10.7	7.1-13.5
	Range	3.2	6.4
Salinity (ppt)	$\bar{x}$	31.67	31.86
	SD	1.41	0.68
	Min-max	28.1-32.7	30.5-32.7
	Range	4.6	2.2
Dissolved oxygen	$\bar{x}$	83.85	86.8
	SD	10.89	21.03
	Min-max	64.9-101.6	62.8-136.0
	Range	36.7	73.2

APPENDIX 2

SPECIES LIST OF NEARSHORE FISHES

COLLECTED BY BEACH SEINE AND TOWNET

Appendix 2. List of all species collected and gear types in which they occurred; BS = beach seine, TN = townet.

Scientific name	Common name	Gear
Squalus acanthias	spiny dogfish	BS,TN
Raja binoculata	big skate	BS
R. stellulata	starry skate	BS
Hydrolagus colliei	ratfish	TN
Clupea harengus pallasi	Pacific herring	BS,TN
Engraulis mordax	northern anchovy	BS,TN
Oncorhynchus gorbuscha	pink salmon	BS,TN
O. kisutch	coho salmon	BS,TN
O. tshawytscha	chinook salmon	BS,TN
Salmo gairdneri	steelhead trout	BS
Hypomesus pretiosus	surf smelt	BS,TN
Spirinchus thaleichthys	longfin smelt	BS,TN
Porichthys notatus	plainfin midshipman	BS
Gobiesox maeandricus	northern clingfish	BS,TN
Gadus macrocephalus	Pacific cod	BS
Microgadus proximus	Pacific tomcod	BS,TN
Theragra chalcogramma	walleye pollock	BS,TN
Aulorhynchus flavidus	tube-snout	BS,TN
Gasterosteus aculeatus	threespine stickleback	BS,TN
Syngnathus griseolineatus	bay pipefish	BS,TN
*Amphistichus rhodoterus**	redtail surfperch	BS
Cymatogaster aggregata	shiner perch	BS,TN
Embiotoca lateralis	striped seaperch	BS,TN
Rhacochilus vacca	pile perch	BS,TN
Trichodon trichodon	Pacific sandfish	BS,TN
Anoplarchus purpurescens	high cockscomb	TN
Lumpenus sagitta	snake prickleback	BS,TN

Appendix 2, cont'd

Scientific name	Common name	Gear
Pholis laeta	crescent gunnel	BS,TN
P. ornata	saddleback gunnel	BS,TN
Ammodytes hexapterus	Pacific sand lance	BS,TN
Sebastes flavidus	yellowtail rockfish	BS
S. melanops	black rockfish	TN
Hexagrammos decagrammus	kelp greenling	BS
H. stelleri	whitespotted greenling	BS
Ophiodon elongatus	lingcod	BS
Artedius fenestralis	padded sculpin	BS
A. lateralis	smoothhead sculpin	BS
Ascelichthys rhodorus	rosylip sculpin	BS,TN
Blepsias cirrhosus	silverspotted sculpin	BS,TN
Chitonotus pugetensis	roughback sculpin	BS
Clinocottus acuticeps	sharpnose sculpin	BS,TN
Enophrys bison	buffalo sculpin	BS,TN
Hemilepidotus hemilepidotus	red Irish lord	BS,TN
Leptocottus armatus	Pacific staghorn sculpin	BS,TN
Myoxocephalus polyacanthocephalus	great sculpin	BS,TN
Nautichthys oculofasciatus	sailfin sculpin	BS,TN
Oligocottus maculosus	tidepool sculpin	BS
Psychrolutes paradoxus	tadpole sculpin	BS,TN
Rhamphocottus richardsoni	grunt sculpin	TN
Scorpaenichthys marmoratus	cabezon	BS
Synchirus gilli	manacled sculpin	TN
Agonopsis emmelane	northern spearnose poacher	BS
Agonus acipenserinus	sturgeon poacher	BS,TN
Bathyagonus nigripinnis	blackfin poacher	TN
Apodichthys flavidus	penpoint gunnel	BS
Occella verrucosa	warty poacher	BS
Odontopyxis trispinosa	pygmy poacher	BS

Appendix 2, cont'd

Scientific name	Common name	Gear
Pallasina barbata	tubenose poacher	BS,TN
Xeneretmus latifrons	blacktip poacher	BS,TN
Eumicrotremus orbis	Pacific spiny lumpsucker	BS,TN
Liparis callyodon	spotted snailfish	BS,TN
L. cyclopus	ribbon snailfish	BS
L. dennyi	marbled snailfish	BS
L. florae	tidepool snailfish	BS,TN
L. mucosus	slimy snailfish	BS
L. pulchellus	showy snailfish	BS,TN
L. rutteri	ringtail snailfish	BS,TN
Citharichthys stigmaeus	speckled sanddab	BS
C. sordidus	Pacific sanddab	BS
Eopsetta jordani	petrale sole	BS
Isopsetta isolepis	butter sole	BS
Lepidopsetta bilineata	rock sole	BS,TN
Parophrys vetulus	English sole	BS,TN
Platichthys stellatus	starry flounder	BS,TN
Pleuronichthys coenosus	C-O sole	BS
Psettichthys melanostictus	sand sole	BS

APPENDIX 3

SUMMARY OF BEACH SEINE BIOLOGICAL DATA

Appendix 3a. Beach seine summary of species richness.

Location	Spring	Summer	Autumn	Winter	$\bar{x}$	SD
Kydaka Beach	7	13	*	7	9.0	2.83
Twin Rivers	10	18	12	12	13.0	3.00
Morse Creek	9	15	11	12	11.8	2.17
Dungeness Spit[1]	8	12	18	5	10.8	4.87
Jamestown	7	6	*	*	6.5	0.50
Beckett Point[1]	21	29	25	30	26.3	3.56
$\bar{x}$	10.3	15.5	16.5	13.2		
SD	4.89	7.04	5.59	8.84		

* indicates no sample obtained.

[1]Combined results of floating and sinking sets.

Appendix-3b. Beach seine summary for density (fish/m^2).

Location	Spring	Summer	Autumn	Winter	$\bar{x}$	SD
Kydaka Beach	0.05	1.75	--	0.02	0.61	0.81
Twin Rivers	0.01	0.74	0.19	0.14	0.27	0.28
Morse Creek	0.01	0.38	0.03	0.02	0.11	0.16
Dungeness Spit*	0.01	1.67	0.06	0.01	0.44	0.71
Jamestown	0.04	0.10	--	--	0.07	0.03
Beckett Point*	0.31	1.18	1.67	2.04	1.30	0.65
$\bar{x}$	0.07	0.77	0.48	0.44		
SD	0.11	0.62	0.68	0.80		

*Average of sinking and floating hauls.

Appendix 3c. Beach seine summary for standing crop (grams/m^2).

Location	Spring	Summer	Autumn	Winter	$\bar{x}$	SD
Kydaka Beach	0.39	6.39	--	1.23	2.67	2.65
Twin Rivers	0.32	7.06	17.85	12.61	9.46	6.51
Morse Creek	1.70	2.03	4.09	0.36	2.04	1.34
Dungeness Spit*	0.32	7.88	1.06	0.06	2.33	3.22
Jamestown	0.12	0.38	--	--	0.25	0.13
Beckett Point*	5.33	6.36	17.01	13.25	10.49	4.84
$\bar{x}$	1.36	5.02	10.00	5.50		
SD	1.85	2.78	7.51	6.08		

*Average of floating and sinking sets.

APPENDIX 4

SUMMARY OF TOWNET BIOLOGICAL DATA

Appendix 4-a. Summary of nearshore fish species richness from townet collections.

Location	Spring	Summer	Autumn	Winter	$\overline{X}$	SD
Kydaka Beach	8	2	9	4	5.7	3.30
Pillar Point	13	5	8	5	7.7	3.77
Twin Rivers	12	13	18	7	10.0	2.94
Morse Creek	23	10	11	7	12.7	7.04
Dungeness Spit	13	12	10	8	10.7	2.21
Jamestown	13	10	13	5	10.2	3.77
Beckett Point	10	13	14	5	10.5	4.04
$\overline{X}$	13.1	9.3	11.9	5.9		
SD	4.74	4.23	3.44	1.46		

Appendix 4-b. Summary of nearshore fish densities (fish/m^3) from townet collections.

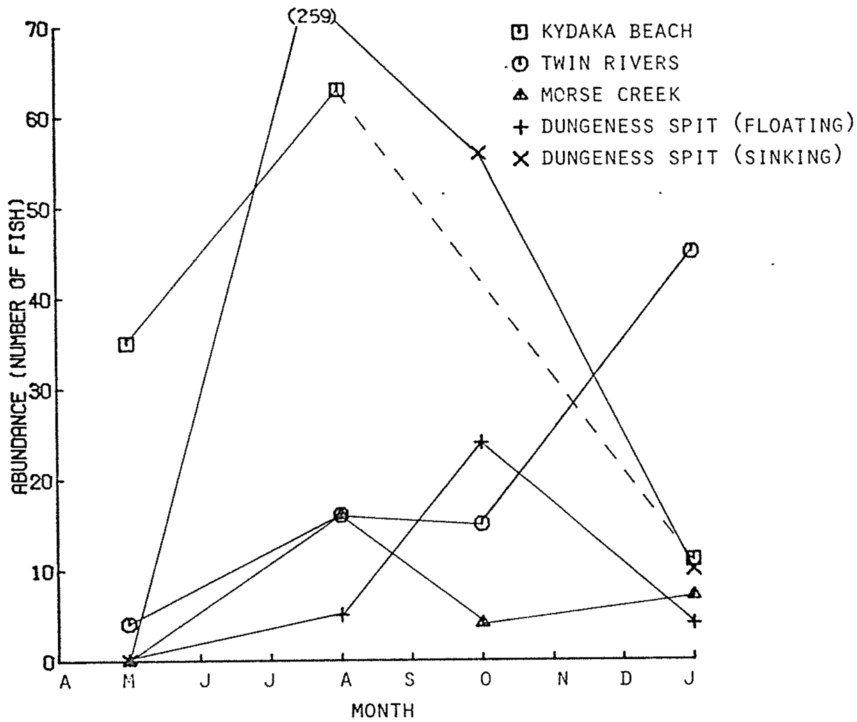
Location	Spring	Summer	Fall	Winter	Mean	SD
Kydaka Beach	0.01	<<0.01	< 0.01	0.01	< 0.01	< 0.01
Pillar Point	0.01	0.03	0.01	< 0.01	0.01	0.01
Twin Rivers	0.11	0.20	0.01	0.01	0.09	0.10
Morse Creek	0.09	< 0.01	0.01	< 0.01	0.02	0.04
Dungeness Spit	0.03	0.04	< 0.01	< 0.01	0.02	0.02
Jamestown	0.02	0.01	< 0.01	< 0.01	< 0.01	< 0.01
Beckett Point	0.09	0.30	0.06	0.01	0.12	0.0127
Mean	0.05	0.08	0.01	0.01		
SD	0.44	0.12	0.02	<<0.01		

Appendix 4-c. Summary of nearshore fish standing crop (grams/m^3) from townet collections.

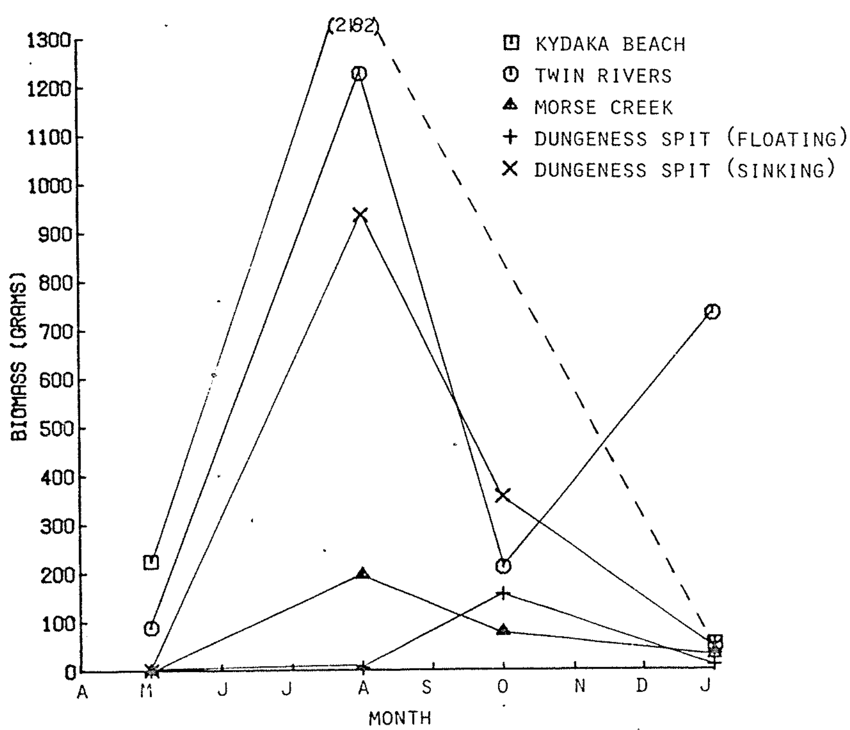
Location	Spring	Summer	Fall	Winter	Mean	SD
Kydaka Beach	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Pillar Point	0.01	0.16	0.01	< 0.01	0.05	0.07
Twin Rivers	0.01	0.27	0.02	0.01	0.08	0.13
Morse Creek	0.01	0.01	0.04	< 0.01	0.02	0.01
Dungeness Spit	< 0.01	0.29	0.08	< 0.01	0.09	0.14
Jamestown	0.03	0.17	0.01	< 0.01	0.05	0.08
Beckett Point	0.04	0.92	0.38	< 0.01	0.34	0.43
Mean	0.02	0.26	0.08	< 0.01		
SD	0.01	0.31	0.14	< 0.01		

APPENDIX 5

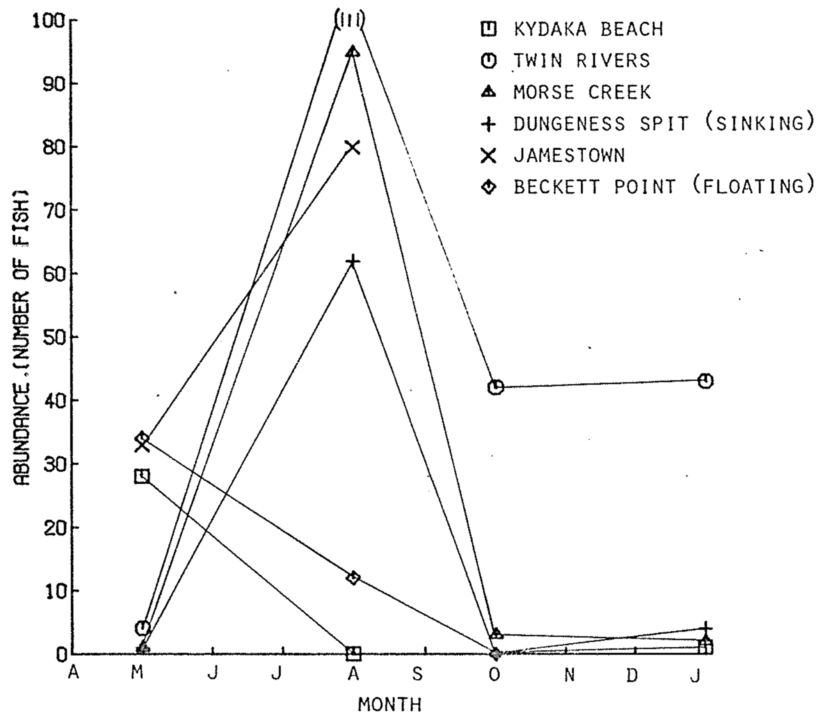
SEASONAL ABUNDANCE AND BIOMASS OF DOMINANT FISH SPECIES IN BEACH SEINE AND TOWNET COLLECTIONS



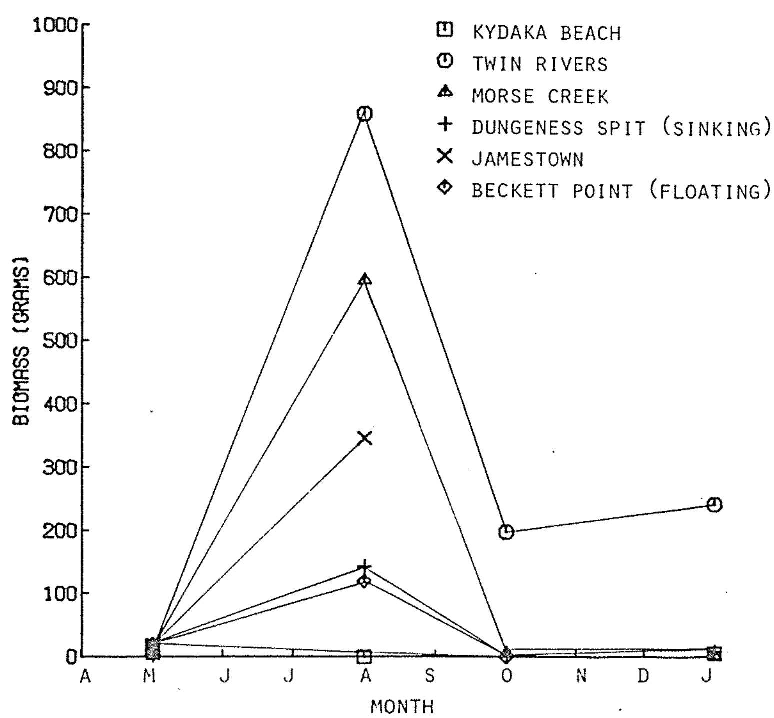
Appendix 5-a. Abundance (numbers) of sand sole from quarterly beach seine collections in the Strait of Juan de Fuca.



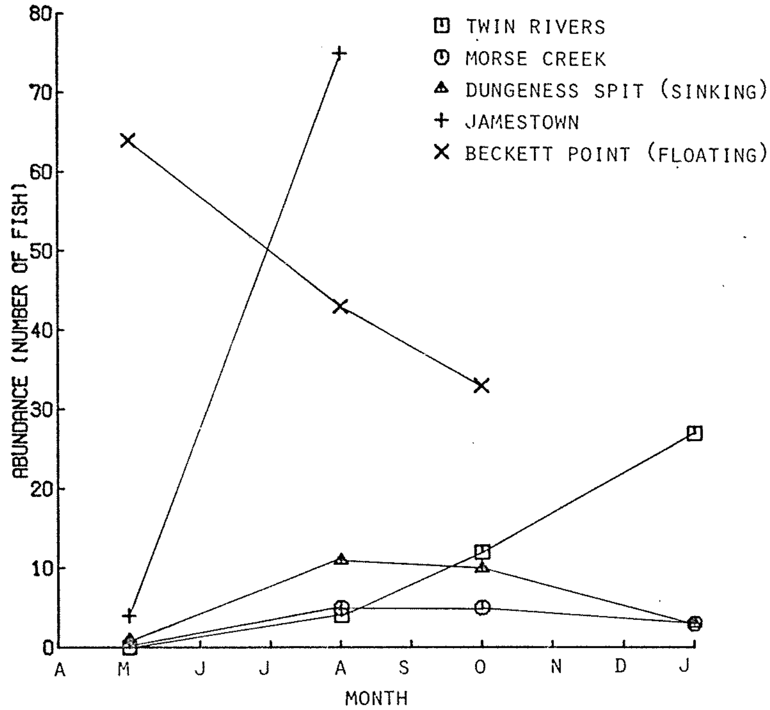
Appendix 5-b. Biomass (gms) of sand sole from quarterly beach seine collections in the Strait of Juan de Fuca.



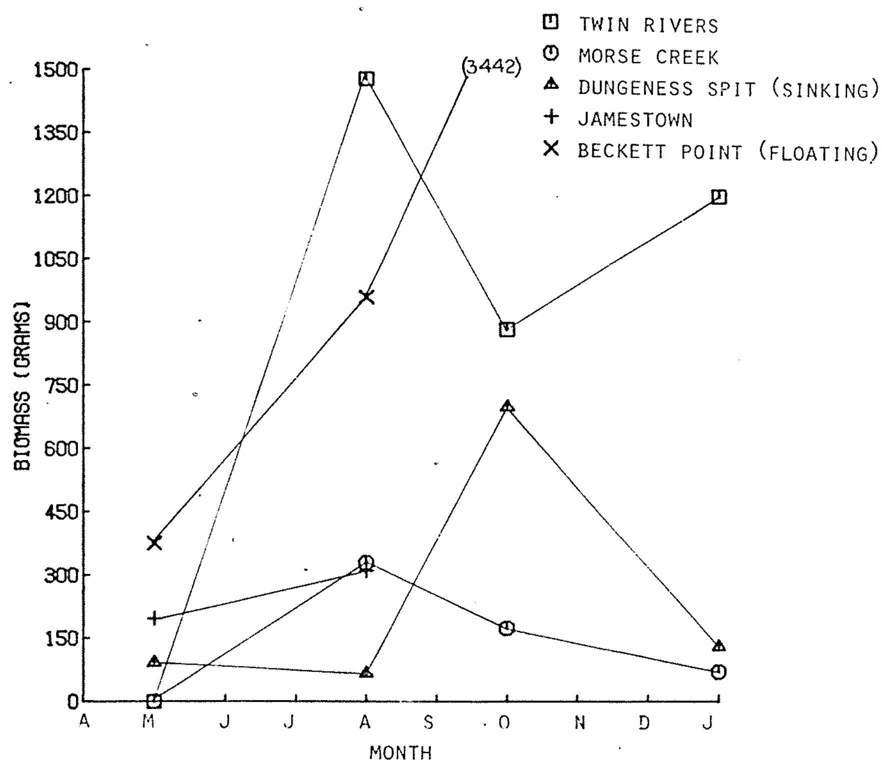
Appendix 5-c. Abundance (numbers) of English sole from quarterly beach seine collections in the Strait of Juan de Fuca.



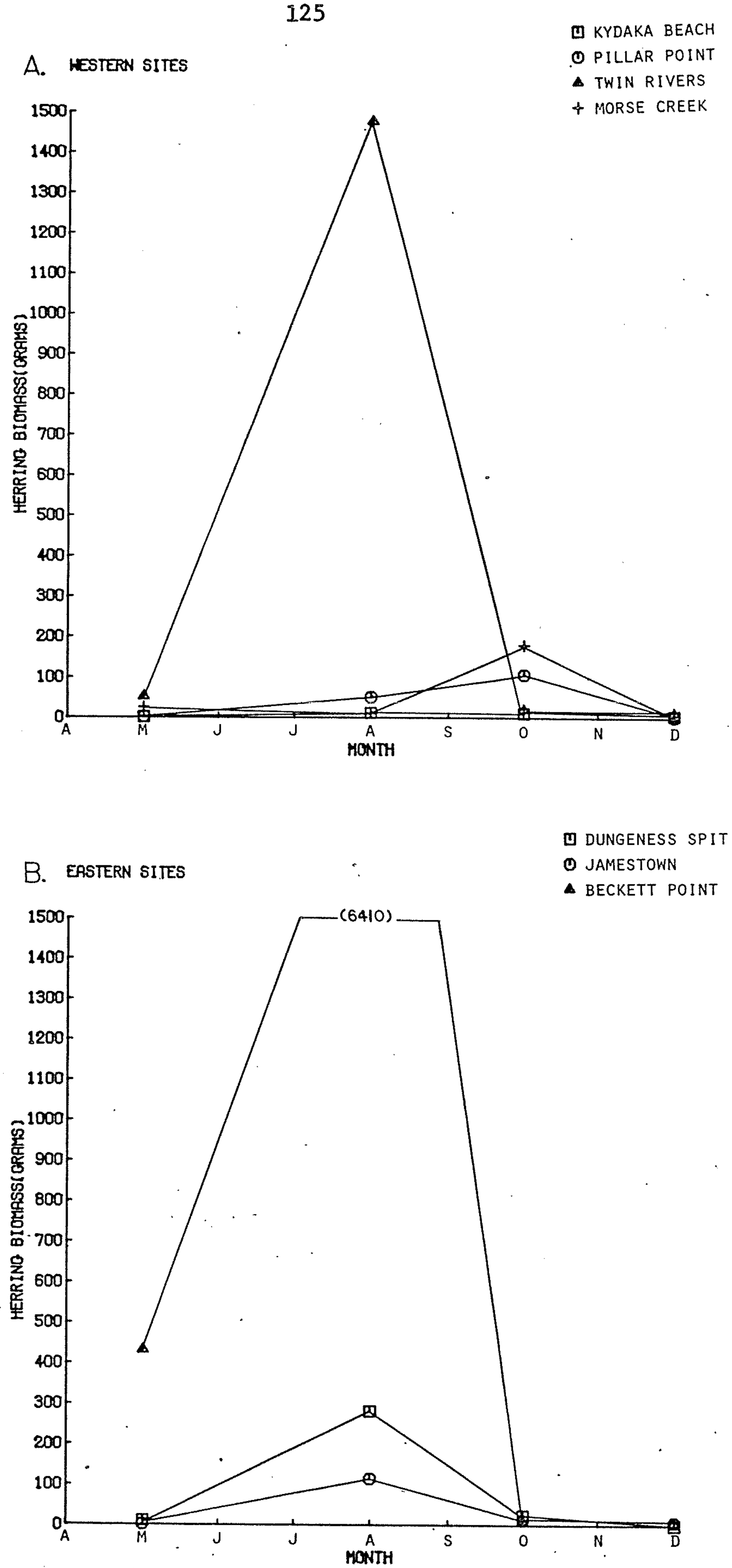
Appendix 5-d. Biomass (gms) of English sole from quarterly beach seine collections in the Strait of Juan de Fuca.



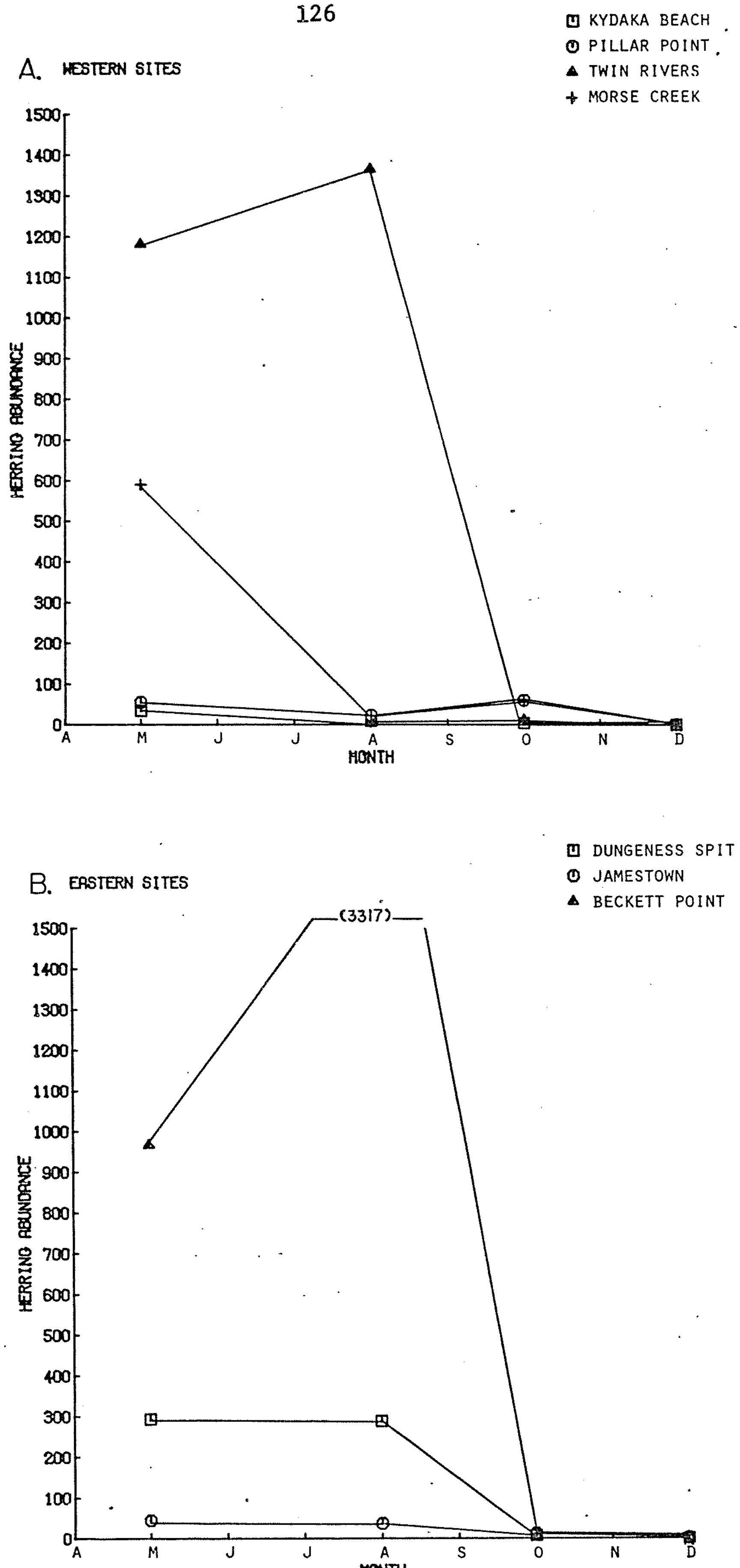
Appendix 5-e. Abundance (numbers) of staghorn sculpin from quarterly beach seine collections in the Strait of Juan de Fuca.



Appendix 5-f. Biomass (gms) of staghorn sculpin from quarterly beach seine collections in the Strait of Juan de Fuca.



Appendix-5-g. Mean biomass (grams) of herring at western sites (A) and eastern sites (B) from quarterly townet collections in the Strait of Juan de Fuca.



Appendix-5-h. Mean number of herring caught at western sites (A) and eastern sites (B) during quarterly townet collections in the Strait of Juan de Fuca.

APPENDIX 6

MACROINVERTEBRATE SPECIES COLLECTED INCIDENTALLY TO BEACH SEINE AND TOWNET COLLECTIONS

Appendix 6. Macroinvertebrates collected coincidentally with nearshore fish surveys in the Strait of Juan de Fuca, May 1976 - January 1977. Sites are indicated by B = Beckett Pt., D = Dungeness Spit, J = Jamestown, K = Kydaka Beach, M = Morse Creek, P = Pillar Pt., and T = Twin Rivers.

	Beach seine	Townet
Phylum Cnidaria		
Class Hydrozoa		
Aequorea aequorea J		x
Hydromedusae sp. P,D,J,B		x
Medusa K,D	x	
Class Anthozoa		
Anthopleura elegantissima B	x	
Phylum Ctenophora		
Beroë spp. D		x
Phylum Platyhelminthes		
Class Turbellaria		
Turbellaria sp. B	x	
Phylum Nemertea		
Nemertea sp. J	x	
Phylum Mollusca		
Class Gastropoda		
Amphissa columbiana B	x	
Littorina scutulata M,B	x	
L. sitkana B	x	
Margarites pupillus B	x	
Nassarius mendicus B	x	
Pollinices lewisi B	x	
Hermissenda crassicornus M,B	x	
Melibe leonina M,B	x	
Class Bivalvia		
Clinocardium nuttalli B	x	
Cryptomya californica J	x	
Class Cephalopoda		
Octopus sp. B	x	x
O. dofleini K		
Phylum Annelida		
Class Polychaeta		
Glycera capitata J		x
Platynereis bicanaliculata P.J.B	x	x
Polychaeta sp. K,T		x
Polynoidea sp. J		x
Tomopteris septentrionalis P,D		x
Phylum Arthropoda		
Class Crustacea		
Order Mysidacea		
Acanthomysis davisi T,M	x	x
A. macropsis K,P,T,D,M,J		x
A. nephrophthalma P,D,M		x
A. sculpta T,D,M,J	x	x
A. sculpta var nuda D,M,J	x	x
Archaeomysis grebnitzki K,P,T,D,M,J	x	x
Boreomysis microps T		x

Appendix 6, cont'd

	Beach seine	Townet
Mysis oculata T,D		x
Neomysis sp. P,D		x
N. kadiakensis K,P,T		x
N. mercedis T		x
N. rayii K,P,T,D,M,J	x	x
Proneomysis wailesi T,D,J	x	x
Mysid sp. K,D	x	
Order Cumacea		
Diastyis sp. T		x
Order Isopoda		
Argeia pugettensis K,T,D	x	
Bopyroides hippolytes B	x	
Gnorimosphaeroma sp. J		x
G. oregonensis K,T,D,M,J	x	x
Idotea fewkesi D,M,J,B	x	
I. rufescens D		x
Ligia pallasi M	x	
Pentidotea montereyensis K,M	x	
P. resecata P,T,D,M,J,B	x	x
P. wosensenskii K,T,D,M	x	x
Rocinela belliceps K,T,D,M,J	x	x
Synidotea angulata J	x	
S. bicuspida K,P,D,J,B		x
Tecticeps pugettensis D		x
Order Amphipoda		
Amphelisca agassizi D		x
A. pugetica D	x	
Amphithoë sp. P		x
A. humeralis D,J,B	x	x
A. lacertosa T,D,J,B	x	x
Anisogammarus confervicolus T	x	
A. pugettensis J,M	x	
Anonyx laticoxae K,D,M,J,B	x	x
Atylus collingi T		x
A. tridens K,P,T,D,M,J,B	x	x
Caprella leviuscula D	x	
Corophium brevis M		x
Gammaridae sp. P,B	x	
Hyale plumulosa B	x	
Melita dendata J,B	x	
Metacaprella kennerlyi B	x	
Orchestoidea pugettensis D	x	
Pontogenia ivanovi D,M	x	x
P. rostrata D,M		x
Westwoodella caecula D,M		x
Order Euphausiacea		
Euphausid sp. T,M		x
Euphausia pacifica P		x
Thysanoessa inermis P		x
T. longipes P		x
T. raschi P		x
T. spinifera P		x

Appendix 6, cont'd

	Beach seine	Townet
Order Decapoda		
Callianassa californiensis J		x
Crangon sp. J,T	x	x
C. alaskensis K,P,T,D,M,J,B	x	x
C. communis B	x	
C. franciscorum T,D,M,J	x	x
C. nigricauda T,D,M,J,B	x	x
C. stylirostris K,T,D,M,J	x	x
Eualus avinus M,J	x	x
E. fabricii T,D,M,J		x
E. pusiolus T,B	x	
E. suckleyi T		x
E. townsendi J		x
Heptacarpus brevirostris T,D,J,B	x	x
H. kincaidi M		x
H. paludicola J	x	
H. sitchensis J,B	x	
H. stimpsoni B	x	
H. stylus M,J,B	x	x
H. taylori J		x
H. tenuissimus K,P,T,M,B	x	x
Pandalus danae D,B	x	x
P. montagui tridens B	x	
P. stenolepis T,D,M,J		x
Sclerocrangon alata D,J		x
Spirontocaris arcuata B	x	
S. snyderi B	x	
Upogebia pugettensis D,J	x	x
Cancer magister K,T,D,M,J,B	x	
C. oregonensis M,B	x	
C. productus D,B	x	
Fabia subquadrata P,D,J		x
Lophopanopeus bellus B	x	
Megalops J,B		x
Oregonia gracilis J,B	x	x
Pagurus armatus B	x	
P. beringanus J,B	x	
P. ganosimanus B	x	
P. hirsutiusculus B	x	
Petrolisthes eriomerus B	x	
Pugettia gracilis P,M,J,B	x	
P. producta P,J,B	x	x
P. richii M,B	x	
Telmessus cheiragonus J,B	x	
Zoea T,D,J,B		x
Phylum Echinodermata		
Class Asteroidea		
Evasterias troscheli	x	
Henricia leviuscula	x	
Class Echinoidea		
Dendraster excentricus	x	

APPENDIX 7

MACROINVERTEBRATE CATALOGUE: RAW

ABUNDANCE OF MACROINVERTEBRATES COLLECTED BY

THE (A) BEACH SEINE AND (B) TOWNET

Appendix 7-a. Raw abundance data of macroinvertebrates collected in the beach seine; biomass in g, size in mm.

BEACH SEINES

Species	May 1976				August 1976				October 1976				January 1977			
	No.	Biomass (gr)	Size $\bar{x}$	Size Range	No.	Biomass (gr)	Size $\bar{x}$	Size Range	No.	Biomass (gr)	Size $\bar{x}$	Size Range	No.	Biomass (gr)	Size $\bar{x}$	Size Range
Site: Jamestown																
Crangon alaskensis	17	5.0	6.4	5.0-9.0												
C. nigricauda	10	5.7	8.3	5.0-10.0	25	23.0	7.3	2.0-13.0								
Heptacarpus brevirostris	9	6.5	7.3	4.0-11.0	2	0.1	3.0	3.0								
H. paludicola	9	1.5	4.5	3.0-4.5												
H. sitchensis	15	1.7	3.1	2.0-4.5												
Upogebia pugettensis	3	0.4			2	2.8			SITE NOT SAMPLED				SITE NOT SAMPLED			
Amphithoë lacertosa	9	1.0			16	1.2										
Anisogammarus pugettensis	1	0														
Melita dendata	3	0														
Idotea fewkesi	1	0														
Pentidotea resecata	6	1.6														
Synidotea angulata	2	0														
Nemertean sp.	1	0														
Polynoidae sp.	10	0.7														
Platynereis bicanaliculata	8	0.4														
Cancer magister					2	--	5.1									
Oregonia gracilis	1	2.1	14.0													
Pugettia gracilis	7	15.2	12.2	8.0-29.0	2	2.8	13.0	10.0-16.0								
Pugettia producta	2	9.5	21.0	18.0-24.0												
Telmessus cheiragonus	19(14)[1]	84.3	22.1	15.0-35.0	7	--	6.0	2.0-7.6								
Cryptomya californica					1	0.2										
Total	137	135.6			57	30.1										

[1]The first number indicates the total number of individuals collected; the number in parentheses indicates the number of individuals used to calculate the average size or weight.

Appendix 7-a, cont'd

B E A C H   S E I N E S

Species	May 1976 No.	May 1976 Biomass (gr)	May 1976 Size $\bar{x}$	May 1976 Size Range	August 1976 No.	August 1976 Biomass (gr)	August 1976 Size $\bar{x}$	August 1976 Size Range	October 1976 No.	October 1976 Biomass (gr)	October 1976 Size $\bar{x}$	October 1976 Size Range	January 1977 No.	January 1977 Biomass (gr)	January 1977 Size $\bar{x}$	January 1977 Size Range
Site: Dungeness Spit (10% sample size)																
Crangon alaskensis	13	6.7	8.0	6.0-10.0	18	15.9	8.6	4.5-13.0								
C. franciscorum					1	0	8.0		11	18.6	12.1	8.0-15.0				
C. nigricauda	1	0.3	10.5	--	10	10.6	10.1	8.0-15.0					21	43.4	12.5	8.0-17.0
C. stylirostris	48	91.4	10.4	6.0-14.0	18	32.3	10.1	5.0-15.0	27	40.6	12.7	9.0-17.0	12	28.8	14.3	9.0-22.0
Pandalus danae					6	6.5	9.6	8.0-16.0	2	6.6	33.5	32-35				
Amphelisca pugetica	1	0														
Anonyx laticoxae									6	1.6	20.5		1	0.2	20	
Atylus tridens	1	0			16	0.7			2	0.1	15.0					
Caprella leviuscula	1	0														
Orchestoidea pugettensis	2	0														
Argeia pugettensis	3	0							3	0.2			2	--		
Gnorimosphaeroma oreg.	2	0			38	3.2										
Pentidotea resecata	1	0														
Cancer magister	1	8.7	37		5	--	6.3	2.5-14.0	24(16)	18.7	17.08	10.2-25.0	4	12.0	26	21.0-32.0
C. productus					1	--	10.16									
Pagurus beringanus					1	5.8							57	1.0	11.72	10-13
Acanthomysis sculpta					126	2.5							49	0.7	13.14	10-15
A. sculpta var. nuda													1	0	11	
Archaeomysis grebnitzkii									1	0						
Neomysis rayii					16	0							1	0.1	22	
Proneomysis wailesi													1	0	17	
Mysid sp.									1	0						
Evasterias troscheli	1	21.6														
Henricia leviuscula					2	38.6										
Medusa sp.													1	0.1	21	
Total	75	128.7			258	116.1			93	86.4			150	86.3		

Appendix 7-a, cont'd

BEACH SEINES

Species	May 1976				August 1976				October 1976				January 1977			
	No.	Biomass (gr)	Size $\bar{x}$	Size Range	No.	Biomass (gr)	Size $\bar{x}$	Size Range	No.	Biomass (gr)	Size $\bar{x}$	Size Range	No.	Biomass (gr)	Size $\bar{x}$	Size Range
Site: Morse Creek																
Crangon alaskensis	2	2.6	9.0	9.0	8	1.9	5.3	5.0-6.5								
C. franciscorum									6	10.5	12.8	9.0-16.0	4	3.3	10.8	9.0-12.0
C. nigricauda	3	7.6	10.7	9.0-12.0	6	6.7	8.1	5.0-12.0								
C. stylirostris	5	9.2	9.7	8.0-15.0	5	6.5	9.1	6.5-13.0	13	16.4	12.2	9.0-17.0	7	13.6	13.1	10.0-15.0
Eualus avinus													4	5.6	11.0	10.0-14.0
Heptacarpus stylus	1	0	4.5													
H. tenuissimus													7	4.3	17.0	15.0-19.0
Anisogammarus pugettensis	3	0.1														
Anonyx laticoxae									1	0.2						
Atylus tridens	37	1.3			1	0.1			1	0.2			1	0.1		
Argeia pugettensis													1	0		
Pontogenia ivanovi													1	0.1		
Gnorimosphaeroma oreg.					1	0										
Idotea fewkesi	5	1.1			1	0.1										
I. wosnesenskii					6	2.1			3	2.0	27.7	23.0-31.0				
Ligia pallasi	1	0.1											1	0.5		
Pentidotea montereyensis													1	0.5		
Pocinela belliceps					2	0							1	0.3		
Cancer magister													10(3)	12.6+	12.7	7.62-40.0
C. oregonensis									1	4.5	23					
Pugettia gracilis	1	0.1	6.5													
P. richii													1	0.7	10.0	

Appendix 7-a, cont'd

BEACH SEINES

Species	May 1976				August 1976				October 1976				January 1977			
	No.	Biomass (gr)	Size x̄	Size Range	No.	Biomass (gr)	Size x̄	Size Range	No.	Biomass (gr)	Size x̄	Size Range	No.	Biomass (gr)	Size x̄	Size Range
Littorina scutulata	1	0														
Acanthomysis davisi	1	0														
A. sculpta					293	8.4										
A. sculpta uar. nuda	29	0.5														
Archaeomysis grebnitzkii	20	0.4											4	0.3	19.5	17.0-23.0
Neomysis rayii					5	0										
Hermissenda crassicornis	29	--														
Melibe leonina	41	--														
Total	179	23.0			328	25.8			25	33.8			42	41.4		
Site: Beckett Pt.																
Crangon alaskensis	13	7.1	7.6	3.0-13.0												
C. communis	6	0.7	3.5	2.5-4.5												
C. nigricauda													15	8.0	10.5	5.0-15.0
Eualus pusiolus									1	--			13	4.5	12.9	6.0-11.0
Heptacarpus brevirostris	30	10.3	4.7	2.5-8.5												
H. sitchensis	42	6.3	3.9	2.5-5.0												
H. stimpsoni	41	2.7	3.4	2.0-5.0												
H. stylus	9	1.3	5.0	3.0-7.5												
Heptacarpus tenuissimus	198	18.6	4.2	2.0-6.0									18	4.3	10.8	5.0-17.0
Pandalus danae	7	7.1	11.3	3.0-14.0	14	36.7	29.6	22.0-38.0	13	32.5	32.2	24.0-40.0	19	18	21.8	15.0-35.0
P. montagui tridens	1	0.1	3.0		1	0.2	13.0						9	0.6	9.3	8.0-11.0
Spirontocaris arcuata													1	0.6	12.0	
S. snyderi	1	0.1	4.0													
Amphithoë humeralis	1	0														
A. lacertosa	2	0														

Appendix 7-a, cont'd

BEACH SEINES

Species	May 1976 No.	May 1976 Biomass (gr)	May 1976 Size $\bar{x}$	May 1976 Size Range	August 1976 No.	August 1976 Biomass (gr)	August 1976 Size $\bar{x}$	August 1976 Size Range	October 1976 No.	October 1976 Biomass (gr)	October 1976 Size $\bar{x}$	October 1976 Size Range	January 1977 No.	January 1977 Biomass (gr)	January 1977 Size $\bar{x}$	January 1977 Size Range
Anonyx laticoxae													1	0.2		
Atylus tridens	5	0														
Gamm. amphipod sp.	2	0														
Hyale plumulosa	1	0														
Melita dendata	1	0														
Metacaprella kennerlyi	3	0														
Bopyroides hippolytes	1	0														
Idotea fewkesi	1	0														
Pentidotea resecata	20	7.7							2	1.1	37	32.0-42.0	9	3.1	30.7	25.0-40.0
Platynereis bicanaliculata	6	0.1														
Turbellaria sp.													6	0.4		
Cancer magister					3	--	6.8	6.4-7.6	4	--	14.6	10.2-17.8	3(1)	1.9	15.04	8.89-21
C. oregonensis	1	0.2	16.0													
C. productus					1	--							3	2.2	12.3	9.0-15.0
Lophopanopeus bellus	1	0.2	11.0													
Oregonia gracilis	24	25.5	10.2	7.0-14.0	2	0.3	5.0	4.0-6.0					2	0.9	8.0	8.0
Pagurus armatus	3	0.9														
P. beringanus													9	56.3		
P. granosimanus													5	1.1		
P. hirsutiusculus	3	0.2			1	1.3							19	12.7		
Petrolisthes eriomerus													1	0.4	8	
Pugettia gracilis	10	6.0	10.5	6.5-17.0												
P. producta					2	13.4	23.0	22.0-24.0	3	54.8	32.3	28.0-40.0	4	21.4	16.8	8-29
P. richii					3	20.0	22.3	22.0-23.0	1	0.8	11.0		5	6.0	12.4	11-14

Appendix 7-a, cont'd

BEACH SEINES

Species	May 1976 No.	May 1976 Biomass (gr)	May 1976 Size $\bar{x}$	May 1976 Size Range	August 1976 No.	August 1976 Biomass (gr)	August 1976 Size $\bar{x}$	August 1976 Size Range	October 1976 No.	October 1976 Biomass (gr)	October 1976 Size $\bar{x}$	October 1976 Size Range	January 1977 No.	January 1977 Biomass (gr)	January 1977 Size $\bar{x}$	January 1977 Size Range
Telmessus cheiragonus					6	2.7	8.0	2.5-13.0	7	78.1	26.3	20.0-49.0	1	7.7	23	
Hermissenda crass.	29				20	--										
Melibe leonina	37	--			1	--							2	6.8		
Amphissa columbiana	2	0														
Clinocardium nuttalli					1	--										
Littorina sculata	1	0.1														
L. sitkana	1	0.1														
Margarites pupillus	32	3.8														
Nassarius mendicus	4	0.2			1	0.6										
Pollinices lewisi					1	--							1			
Dendraster excentricus	2	0.1														
Anthopleura elegant.					1	0.9										
Octopus sp.													1	--		
Total	541	99.4			58	76.1			31	167.3			147	160.7		
Site: Twin Rivers																
Crangon sp.	2	1.4	0													
C. alaskensis	2	3.8	10.0	10.0												
C. nigricauda	11	11.9	8.5	7.0-12.0	47	64.4	8.7	4.0-14.0					10	18.1	13.3	12-17
C. styliostris	7	10.2	10.3	8.5-12.0	2	1.4	7.5	5.0-10.0					3	6.6	14.7	13-18
Eualus pusiolus													4	2.4	7.3	5.0-8.0
Heptacarpus brev.	5	3.9	7.1	6.0-7.5	7	5.2	5.8	3.0-8.0								
Amphithoë lacertosa	1	0														
Anisogam. confervicolus					1	0										
Atylus tridens	2	0			15	0										

Appendix 7-a, cont'd

B E A C H   S E I N E S

Species	May 1976				August 1976				October 1976				January 1977			
		Biomass	Size			Biomass	Size			Biomass	Size			Biomass	Size	
	No.	(gr)	$\bar{x}$	Range	No.	(gr)	$\bar{x}$	Range	No.	(gr)	$\bar{x}$	Range	No.	(gr)	$\bar{x}$	Range
Argeia pugettensis					1	0										
Idotea fewkesi					1	0.3										
I. wosnesenskii					1	0.1										
Rocinela belliceps													1	0.4	22	
Cancer magister					86	--	10.9	5.1-17.8	40	0	12.4	7.6-17.8	4	--	15.56	7.62-15.24
Acanthomysis sculpta					9	0.1										
Total	30	31.2			170	71.5			40	0			22	27.5		
Site: Kydaka Pt.																
Crangon stylirostris	28	65.0			20	34.4	10.0	5.5-15.0					36	64.7	14.1	10-20
Argeia pugettensis	5	0											2	--		
Gnorimosphaeroma oreg.					1	0.1			SITE NOT SAMPLED							
Idotea wosnesenskii					2	0.4										
Pentidotea montereyensis													1	0.2	25	
Cancer magister	2	--	5.3	5.0-5.5									1	2.3	23	
Medusa sp.													2	3.9		
Unident. mysid													7	0.2	14.1	
Total	35	65.0			23	34.9							49	71.3		

Appendix 7-b. Raw abundance data of macroinvertebrates collected in the townet; biomass in g, size in mm.

TOWNET SAMPLES

Species	May 1976				August 1976				December 1976				October 1976			
	No.	Biomass (gr)	Size $\bar{x}$	Size Range	No.	Biomass (gr)	Size $\bar{x}$	Size Range	No.	Biomass (gr)	Size $\bar{x}$	Size Range	No.	Biomass (gr)	Size $\bar{x}$	Size Range
Site: Jamestown																
Callianassa californiensis					1	4.7	67	--								
Crangon sp.	1	0.1	5.5	--												
C. alaskensis	85	16.8	5.4	2.5-7.0					52	5.7	6.5	4-13				
C. franciscorum					13	3.6	6.8	5-12					49	18.9	7.0	3-13
C. stylirostris	1	0	5.3	--												
Eualus avinus													2	0.8		
E. fabricii					35	6.0	10.7	7-18	7	2.0	--	--	60	21.9	14.6	8-20
E. townsendi													7	0.9	10.9	9-15
Heptacarpus stylus																
H. taylori									18	2.3	--	--				
Pandalus stenolepis													7	7.3	24.7	20-30
Sclerocrangon alata									2	0.1	18	16-20				
Amphithoë humeralis					7	0.9	22.1	19-30					4	0.7	23.5	20-27
Anonyx laticoxae					3	0.3	17.3	17-18	94	17.3	22.4	19-25	4	0.8	19	18-20
Atylus tridens	79	5.1	--	--	17	1.0	17.7	11-22	6	6.2	20.2	18-22	40	3.7	16.2	12-23
Gnorimosphaeroma sp.													3	0.2	8.7	7-10
G. oregonensis					1	0	9	--								
Pentidotea resecata	1	0.1	--	--									1	0.7	37	--
Rocinela belliceps					1	0.1	11	--								
Synidotea bicuspida	94	5.9	--	--												
Glycera capitata									1	2.8	115	--				
Fabia subquadrata	3	0.1	3.7	3.0-4.0												
Crab megalops					3	0.1	--	--								

Appendix 7-b, cont'd

TOWNET SAMPLES

Species	May 1976 No.	May 1976 Biomass (gr)	May 1976 Size $\bar{x}$	May 1976 Size Range	August 1976 No.	August 1976 Biomass (gr)	August 1976 Size $\bar{x}$	August 1976 Size Range	December 1976 No.	December 1976 Biomass (gr)	December 1976 Size $\bar{x}$	December 1976 Size Range	October 1976 No.	October 1976 Biomass (gr)	October 1976 Size $\bar{x}$	October 1976 Size Range
Crab zoea																
Aequorea aequorea					2	0.5	24	23-25	1	2.7	55	--	4	3.0	48.5	38-55
Hydromedusa sp.	200	0,3	--	--												
Acanthomysis macropsis																
A. sculpta													6	0.1	11.8	10-13
A. sculpta var. nuda													1	0		
Archaeomysis grebnitzkii													3	0.2	17.7	17-18
Proneomysis wailesi													6	0.4	15.5	13-21
Totals	464	28.4			83	17.2			181	39.1			197	59.6		
Site: Dungeness Spit																
Crangon alaskensis	7	2.7	6.8	5.0-8.0					50	16.0	7.8	7-11				
C. franciscorum					13	1.5	5.6	3-8								
C. nigricauda									1	0.2	7	--				
Eualus fabricii					12	2.1	10.2	6-21	71	18.1	13.7	9-19				
Heptacarpus brevirostris									3	0.5	5	4-7				
Pandalus danae									1	0.9	22					
P. stenolepis					1	0.5	18	--								
Sclerocrangon alata					1	0.3	6	--								
Upogebia pugettensis	1	0.1	--	--												
Amphilisca agassizi					1	0	--	--								
Amphithoë humeralis					2	0	7	4-10	3	0.4	20	19-21				
Anonyx laticoxae					1	0.1	15	--	1	0.2	21	--				
Atylus tridens	24	1.1	--	--	184	15.6	16.4	4-21	39	4.9	18.6	11-23				

Appendix 7-b, cont'd

TOWNET SAMPLES

Species	May 1976 No.	May 1976 Biomass (gr)	May 1976 Size $\bar{x}$	May 1976 Size Range	August 1976 No.	August 1976 Biomass (gr)	August 1976 Size $\bar{x}$	August 1976 Size Range	December 1976 No.	December 1976 Biomass (gr)	December 1976 Size $\bar{x}$	December 1976 Size Range	October 1976 No.	October 1976 Biomass (gr)	October 1976 Size $\bar{x}$	October 1976 Size Range
Pontogenia ivanovi									1	0.1	17	--		SITE NOT		
P. rostrata	6	0.1	--	--										SAMPLED		
Westwoodilla caecula									3	0.1	13	--				
Gnorimosphaeroma oregonensis	2	0	--	--					1	0	7	--				
Idotea rufescens					1	0.1	15	--								
Pentidotea resecata									1	0.1	22	--				
P. wosensenski					2	0.2	13	8-18								
Rocinela belliceps					1	0.1	14	--								
Synidotea bicuspida	1	0	--	--					1	0	12	--				
Tecticeps pugettensis					59	6.5	11.9	8-18								
Tomopteris septentrionalis	6	0	--	--												
Fabia subquadrata	4	0.1	3.3	2.5-4.0												
Crab zoea					5	0.1	--	--	1	0	--	--				
Hydromedusa	31	--														
Beroë sp.									2	0.4	21	19-23				
Thysanoessa inermis																
Acanthomysis macropsis					5	18.0	5.8	15-22	6	0.1	16.2	13-18				
A. nephrophthalma	2	0	--						1	0	17	--				
A. sculpta					14	0.4	14.1	13-15	124	2.0	9.5	9-12				
A. sculpta var. nuda									1	0	17	--				
Archaeomysis grebnitzkii	34	2.3							121	6.8	18	13-20				
Mysis oculata					22	1.0	15.5	13-22								
Neomysis sp.									1	0	--	--				
Neomysis rayii					1	0.1	24	--								

Appendix 7-b, cont'd

TOWNET SAMPLES

Species	May 1976				August 1976				December 1976				October 1976			
	No.	Biomass (gr)	Size $\bar{x}$	Size Range	No.	Biomass (gr)	Size $\bar{x}$	Size Range	No.	Biomass (gr)	Size $\bar{x}$	Size Range	No.	Biomass (gr)	Size $\bar{x}$	Size Range
Proneomysis wailesi									4	0.1	15.5	13-18				
Mysid, unidentified									5	0	12.4	12-13				
Total	118	6.4			325	46.6			442	50.9						

Appendix 7-b, cont'd

TOWNET SAMPLES 1976

Species	May No.	May Biomass (g)	May Size x̄	May Size Range	August No.	August Biomass (g)	August Size x̄	August Size Range	December No.	December Biomass (g)	December Size x̄	December Size Range
Site: Kydaka												
Crangon alaskensis	NOT SAMPLED				NOT SAMPLED				9	1.9	6.3	2-18
Heptacarpus tenuissimus									6	0.4	8.3	5-11
Anonyx laticoxae									1	0.2	20	--
Atylus tridens									7	0.5	19.7	12-21
Rocinela belliceps									1	0.2	16	--
Synidotea bicuspida									1	0	7	--
Polychaeta									1	0	--	--
Acanthomysis macropsis									60	2.3	17.5	12-21
Archaeomysis grebnitzkii									9	0.2	14.6	11-16
Neomysis kadiakensis									10	0.3	17.1	14-22
Neomysis rayii									10	0.4	19.3	14-22
Octopus dofleini									1	0.7	12	--
Total									116	7.1		
Site: Pillar Point												
Crangon alaskensis	1	0.1	7.0	--					NOT SAMPLED			
Heptacarpus tenuissimus					2	1.1	16.5	12-21				
Amphithoë sp.					1	0.5	34					
Atylus tridens	2	0	--	--								
Gam. amphipod sp.					1	0	4	--				
Pentidotea resecata					1	0.6	39	--				
Synidotea bicuspida	1	0	--	--								
Platynereis bicanaliculata	1	0	--	--								
Tomopteris septentrionalis	1	0	--	--								
Fabia subquadrata	1	0	1.5	--								

Appendix 7-b, cont'd

TOWNET SAMPLES 1976

Species	May				August				December			
	No.	Biomass (g)	Size $\bar{x}$	Size Range	No.	Biomass (g)	Size $\bar{x}$	Size Range	No.	Biomass (g)	Size $\bar{x}$	Size Range
Pugettia gracilis					2	12.5	19.5	11-28				
P. producta					1	14.8	31	--				
Hydromedusa	71	--	--	--								
Euphausia pacifica	6	0.1	--	--								
Thysanoessa longipes	16	1.3	--	--								
T. raschi	22	0.3+										
T. spinifera	7	0	--	--								
Acanthomysis macropsis	3	0	--	--								
A. nephrophthalma	1	0	--	--								
Archaeomysis grebnitzkii	1	0	--	--								
Neomysis sp.					4	0.2	20.8	15-24				
N. kadiakensis	2	0	--	--								
N. rayii	3	0	--	--								
Total	139	1.8			12	29.7						
Site: Beckett Point												
Crangon alaskensis	11	0.9	4.3	2.0-5.0					NOT SAMPLED			
Pandalus danae					4	5.3	21.0	18-25				
Atylus tridens	3	0	--	--								
Synidotea bicuspida	5	0	--	--								
Crab megalops	1	0	--	--								
Crab zoea	26	0	--	--								
Hydromedusae	112	0	--	--								
Total	158	0.9			4	5.3						

Appendix 7-b, cont'd

TOWNET SAMPLES 1976

Species	May				August				December			
	No.	Biomass (g)	Size $\bar{x}$	Size Range	No.	Biomass (g)	Size $\bar{x}$	Size Range	No.	Biomass (g)	Size $\bar{x}$	Size Range
Site: Morse Creek												
Crangon alaskensis	3	0	6.9	6.5-7.0					80	24.4	10.2	2-14
C. franciscorum					3	0.5	5.3	3-8				
Eualus fabricii												
Heptacarpus kincaidi					19	1.4	8.5	6-10	1	0.5	8	--
H. stylus	40	6.6	5.10	4-8								
H. tenuissimus									13	1.9	5.7	4-8
Pandalus stenolepis					2	1.8	24	--				
Anonyx laticoxae									6	1.2	22.3	20-24
Atylus tridens	6	0	--	--	3	0.2	16.3	16-17	23	2.3	19.2	15-23
Corophium brevis									1	0	15	--
Pontogenia rostrata	1	0	--	--								
Westwoodilla caecula									7	0.2	12	11-13
Gnorimosphaeroma oregonensis	4	0.1	--	--								
Pentidotea resecata	3	0.1	--	--								
Rocinela belliceps	1	0	--	--					1	0.1	15	--
Euphausiid (unident.)									1	0.1	18	--
Acanthomysis macropsis									4	0	14.5	12-17
A. nephrophthalma	1	0	--	--								
A. sculpta	6	0	--	--								
Archaeomysis grebnitzkii	159	6.4	--	--					317	16.6		
Neomysis rayii	3	0	--	--					214	5.8		
Beroë sp.									2	0.5	25	20-30
Total	227	13.2			27	3.9			670	53.6		

Appendix 7-b, cont'd

TOWNET SAMPLES 1976

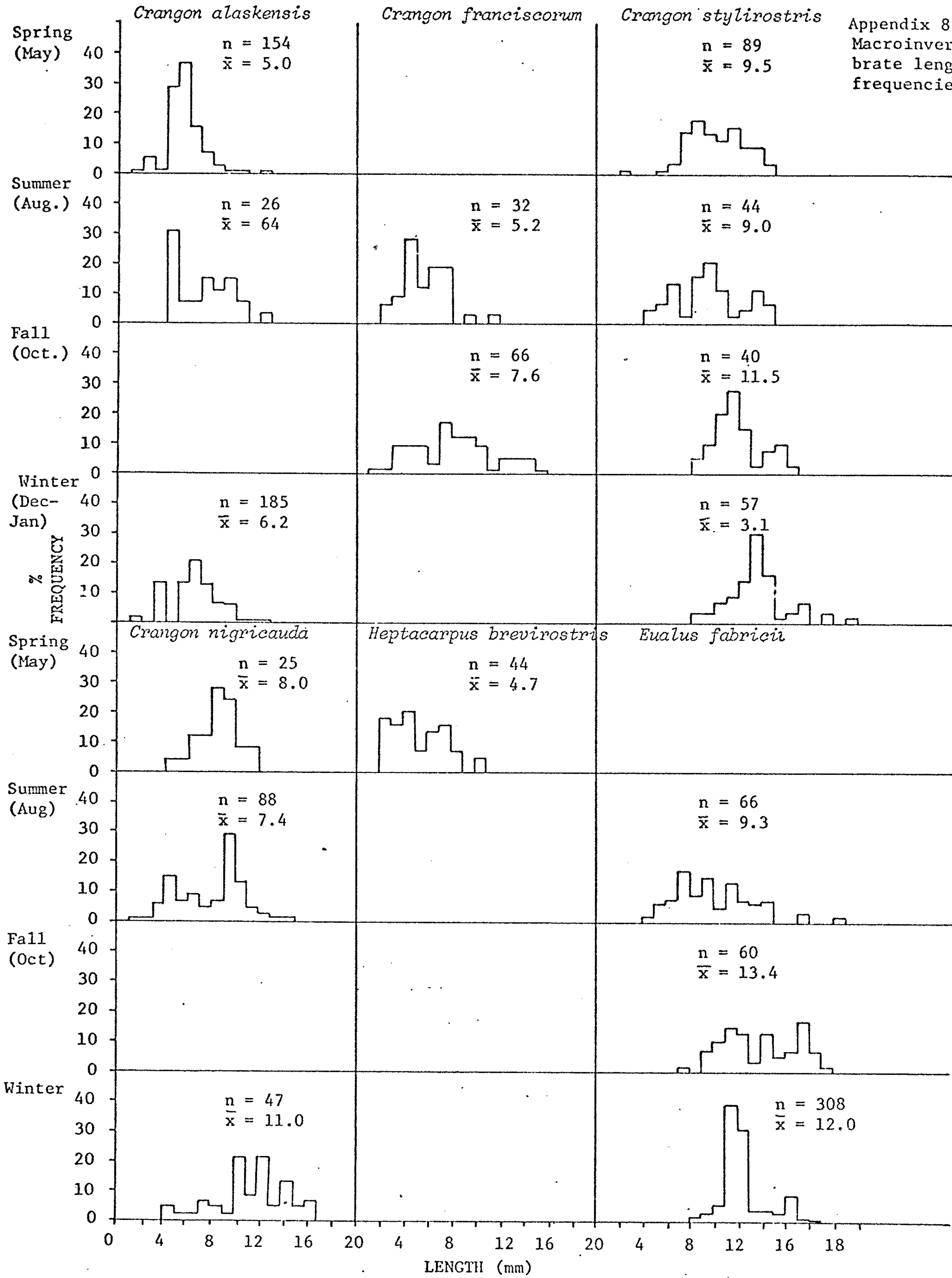
Species	May No.	May Biomass (g)	May Size $\bar{x}$	May Size Range	August No.	August Biomass (g)	August Size $\bar{x}$	August Size Range	December No.	December Biomass (g)	December Size $\bar{x}$	December Size Range
Site: Twin Rivers												
Crangon alaskensis									5	1.3	6.6	2-11
C. franciscorum					2	0.3	5.5	4-7				
Eualus fabricii									237	41.0	12.8	10-19
E. suckleyi												
Heptacarpus tenuissimus									39	8.7	6.2	5-11
Pandalus stenolepis												
Atylus collingi									1	0	11	--
A. tridens	13	0.2			3	0.2	14.1	12-18	4	0.2	17.3	10-20
Gnorimosphaeroma oregonensis					3	0.1	8	--	1	0	7	--
Pentidotea resecata					2	0.3	18.5	12-25	6	0.8	19	13-29
Rocinela belliceps					1	0.2	18	--				
Polychaeta sp.									2	0.2	--	--
Crab zoea					1	0	--	--				
Euphausid sp.									2	0.2	21.5	19-24
Acanthomysis davisi	7	0.1										
A. macropsis	40	1.8							52	1.4	15.8	10-22
A. sculpta									8	0.1	11.1	10-12
Archaeomysis grebnitzkii									4	0.2	22	14-30
Boreomysis microps									3	0.1	19.3	18-21
Mysis oculata									2	0.1	20.5	20-21
Neomysis kadiakensis	19	0.1										
N. mercedis									4	0.2	18.3	15-20
N. rayii	2555	91.9			30	4.8	22.4	20-25	1856	61.6		
Proneomysis wailesi					57	3.4	18.9	11-25				
Diastylus sp.									3	0	6.3	5-9
Total	2634	94.1			99	9.3			2229	116.1		

APPENDIX 8

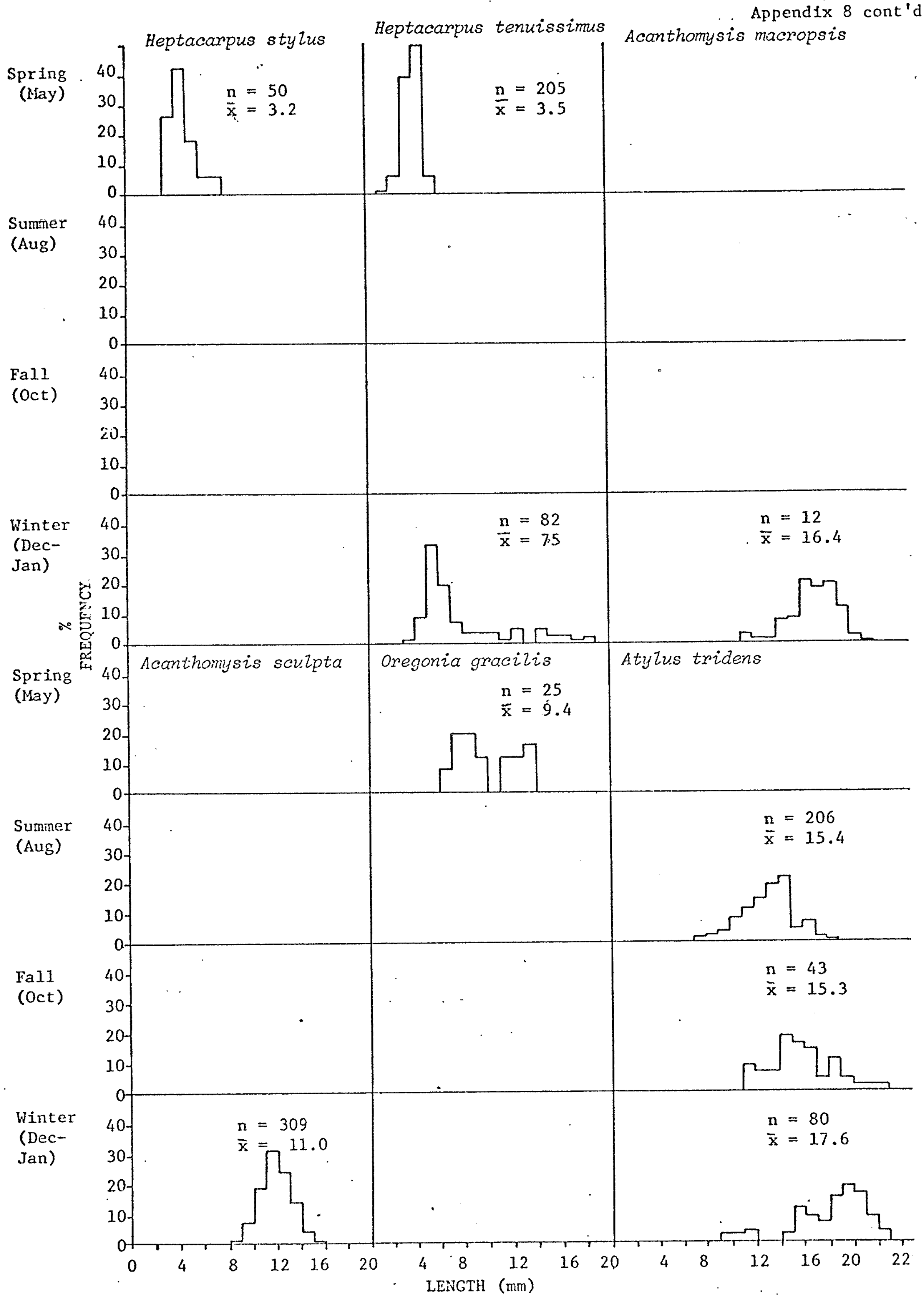
MACROINVERTEBRATE LENGTH

FREQUENCIES

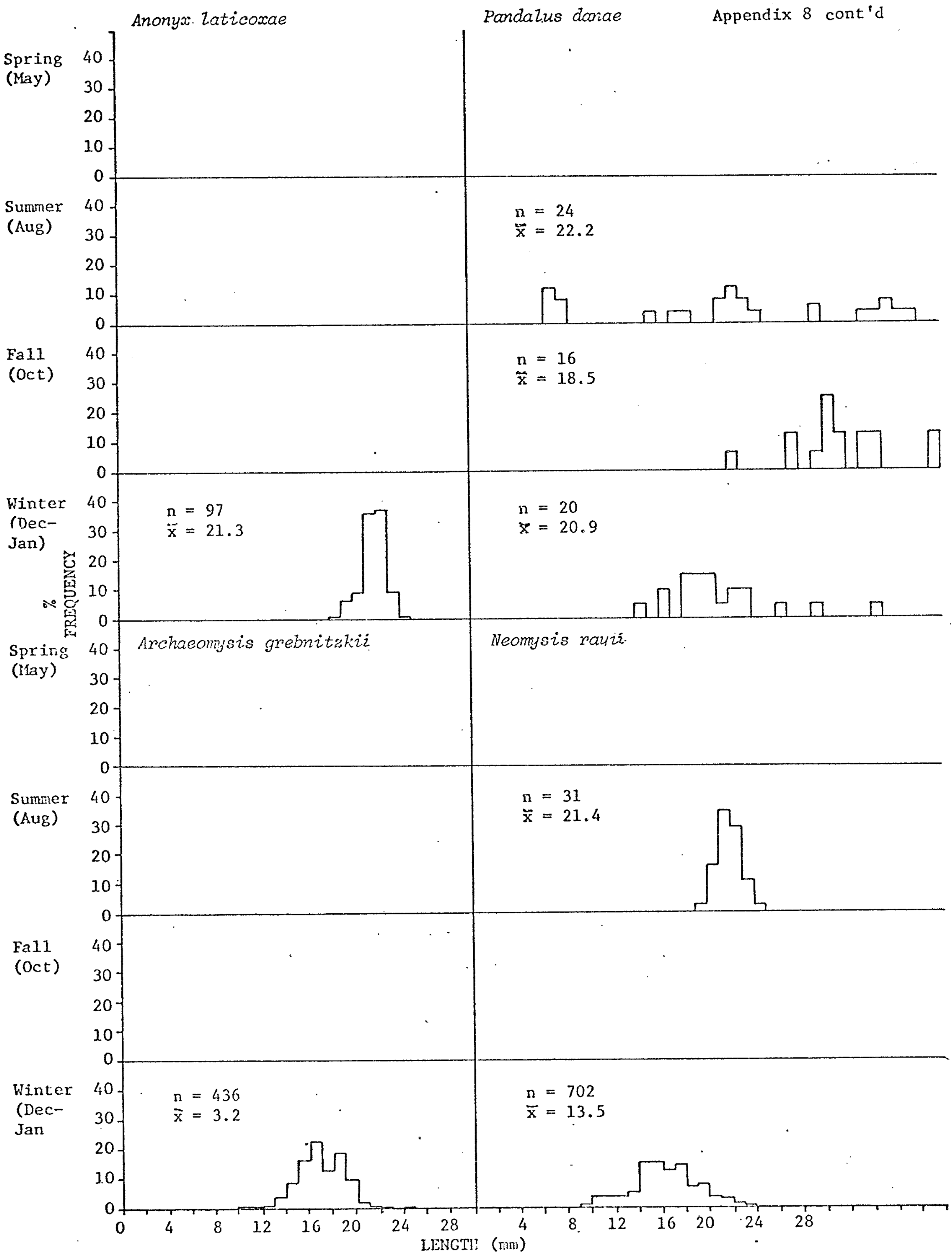
Appendix 8 Macroinvertebrate length frequencies.



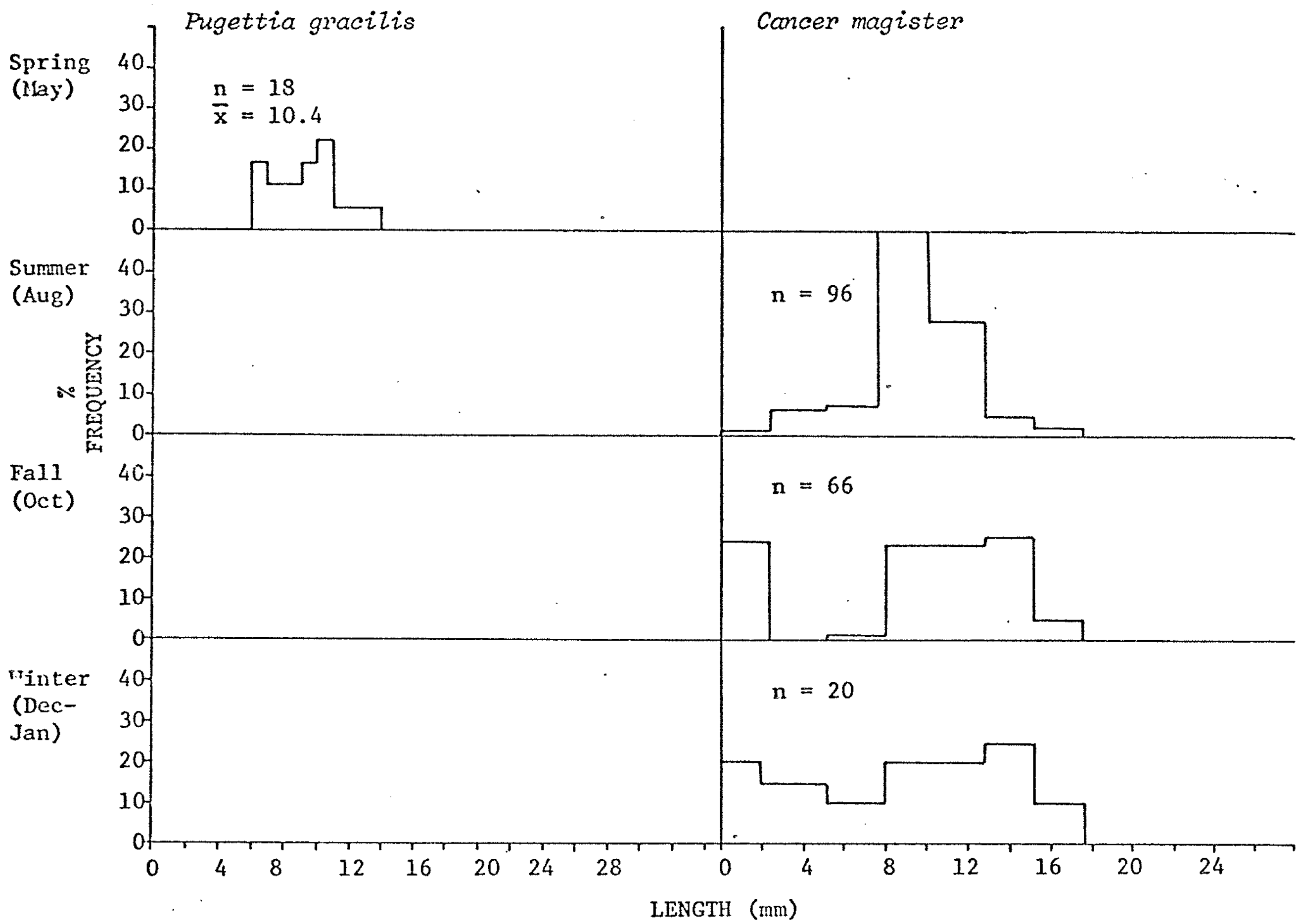
Appendix 8 cont'd



Appendix 8 cont'd



Appendix 8 cont'd



APPENDIX 9

PREY ITEMS CONSUMED BY NEARSHORE (A) DEMERSAL AND (B) NERITIC FISHES

Appendix 9-a. Prey items consumed by nearshore demersal fishes, Strait of Juan de Fuca, May 1976 - January 1977, and percentage that taxon composes of total consumed items.

Prey item	% Composition
Algae	1.4
Division Chlorophyta	0.8
Division Rhodophyta	0.4
Division Anthophyta	
Phyllospadix scouleri	0.1
Zostera marina	0.3
Phylum Cnidaria	
Class Hydrozoa	< 0.1
Phylum Platyhelminthes	
Class Turbellaria	< 0.1
Class Trematoda	0.3
Phylum Nemertea (Rhynchocoela)	0.1
Phylum Nematoda	1.1
Phylum Annelida	< 0.1
Class Polychaeta	9.2
Family Nereidae	0.1
Family Glyceridae	0.1
Family Goniadidae	< 0.1
Family Arenicolidae	0.1
Class Oligochaeta	0.3
Class Hirudinea	< 0.1
Phylum Mollusca	0.1
Class Gastropoda	1.1
Class Pelecypoda	3.0
Yoldia scissurata	< 0.1
Clinocardium nuttalli	0.2
Clinocardium spp.	< 0.1
Family Mytilidae	< 0.1
Phylum Arthropoda	
Class Pycnogonida	0.1
Class Arachnida	< 0.1
Class Crustacea	0.5

Appendix 9-a, cont'd

Prey item	% Composition
Subclass Ostracoda	0.3
Subclass Copepoda	
Order Harpacticoida	3.7
Order Calanoida	3.1
Order Cyclopoida	0.3
Subclass Branchiura	< 0.1
Subclass Cirripedia	
Order Thoracica	0.3
Subclass Malacostraca	
Order Leptostraca	
Nebaliacea	0.7
Order Mysidacea	11.4
Family Mysidae	0.6
Acanthomysis sp.	< 0.1
Neomysis sp.	0.9
Order Cumacea	3.9
Order Tanaidacea	4.5
Leptochelia sp.	< 0.1
Order Isopoda	0.3
Suborder Valifera	1.5
Family Idoteidae	0.4
Pentidotea spp.	0.1
P. resecata	< 0.1
P. wosnesenskii	< 0.1
Synidotea nebulosa	< 0.1
Idotea fewkesi	0.1
Idotea sp.	0.1
Suborder Flabellifera	1.7
Family Sphaeromatidae	0.6
Gnorimosphaeroma oregonensis	0.9
Suborder Epicardia	< 0.1
Suborder Anthuridea	0.2
Suborder Microcerberidea	< 0.1
Order Amphipoda	

Appendix 9-a, cont'd

Prey item	% Composition
Suborder Hyperiidea	< 0.1
Suborder Gammaridae	22.3
Atylus tridens	< 0.1
Family Corophidae	0.1
Suborder Caprellidae	0.5
Order Euphausiacea	0.1
Order Decapoda	0.1
Suborder Natantia	3.4
Family Pandalidae	0.7
Pandalus spp.	< 0.1
P. danae	0.1
Pandalopsis ampla	< 0.1
P. dispar	< 0.1
Family Hippolytidae	1.4
Heptacarpus spp.	0.1
H. kincaidi	< 0.1
H. sitchensis	< 0.1
Heptacarpus sp.	0.1
Family Crangonidae	2.0
Crangon spp.	0.3
C. alaskensis	< 0.1
C. abyssorum	< 0.1
Sclerocrangon alata	< 0.1
Suborder Reptantia	1.3
Section Astacura	
Family Callianassidae	0.1
Ubogebia pugettensis	< 0.1
Section Anomura	0.2
Family Paguridae	0.4
Pagurus hirsutiusculus	< 0.1
Haplogaster mertensi	< 0.1
Section Brachyura	0.1
Cancer spp.	< 0.1
C. productus	< 0.1
C. magister	0.2
C. gracilis	0.1

Appendix 9-a, cont'd

Prey item	% Composition
Hemigrapsus oregonensis	< 0.1
Pugettia spp.	< 0.1
P. gracilis	< 0.1
Telmessus cheiragonus	0.3
Family Xanthidae	0.1
Pinnixa spp.	< 0.1
Class Insecta	0.2
Order Diptera	< 0.1
Phylum Echinodermata	
Class Echinoidea	0.1
Dendraster excentricus	< 0.1
Class Holothuroidea	0.7
Parastichopus californicus	0.1
Phylum Chordata	
Subphylum Urochordata	0.4
Class Larvacea	0.1
Fritillaria borealis	< 0.1
Class Ascidiacea	< 0.1
Subphylum Vertebrata	
Class Osteichthys	2.6
Family Salmonidae	< 0.1
Family Gobiesocidae	< 0.1
Family Gasterosteidae	
Aulorhynchus flavidus	0.1
Order Perciformes	0.1
Family Scorpaenidae	< 0.1
Family Hexagrammidae	< 0.1
Family Embiotocidae	0.2
Cymatogaster aggregata	< 0.1
Family Stichaeidae	< 0.1
Family Pholidae	< 0.1
Pholis ornata	< 0.1
Family Ammodytidae	0.2
Family Cottidae	

Appendix 9-a, cont'd

Prey item	% Composition
Family Pleuronectidae	< 0.1
Parophrys vetulus	< 0.1
Rocks	0.5
Detritus	2.0

Appendix 9-b. Prey items consumed by neritic fishes, Strait of Juan de Fuca, May 1976 - January 1977, and percent that taxon composes of total consumed items.

Prey item	% Composition
Phylum Ctenophora	0.7
Phylum Nematoda	0.6
Phylum Annelida	
Class Polychaeta	1.5
Family Phyllodocidae	0.2
Family Syllidae	0.2
Family Nereidae	0.2
Phylum Mollusca	
Class Gastropoda	0.2
Class Pelecypoda	0.2
Phylum Arthropoda	
Class Crustacea	2.1
Subclass Ostracoda	1.9
Subclass Copepoda	
Order Harpacticoida	4.5
Order Calanoida	22.4
Order Cyclopoida	0.4
Order Caligoida	0.2
Subclass Cirripedia	
Order Thoracica	1.7
Subclass Malacostraca	
Order Mysidacea	6.7
Order Cumacea	6.2
Order Tanaidacea	1.3
Order Isopoda	
Suborder Anthuridea	0.2
Suborder Valvifera	1.5
Order Amphipoda	
Suborder Hyperiidea	3.5
Suborder Gammaridea	13.6
Suborder Caprellidea	0.9

Appendix 9-b, cont'd

Prey item	% Composition
Order Euphausiacea	3.9
Order Decapoda	1.1
Suborder Natantia	
Family Pandalidae	0.6
Pandalus platyceros	0.2
P. danae	0.2
Family Hippolytidae	0.9
Family Crangonidae	0.6
Suborder Reptantia	3.9
Class Insecta	1.9
Phylum Chordata	
Subphylum Urochordata	0.6
Class Larvacea	4.3
Subphylum Teleostei	3.0
Family Clupeidae	0.2
Section Brachyura	0.2
Detritus	0.6